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RESEARCH ON INSECT BORERS OF HARDWOODS

CURRENT STATUS, NEEDS, AND APPLICATION

Proceedings of a Research Coordination Meeting
Delaware, Ohio
March 30-31, 1976

Forest Insect and Disease Research, Forest Service
U.S. Department of Agriculture, Washington D.C.

Cover: Drawing by James W. Lockyer, Biological Laboratory Technician, Northeastern Forest Experiment Station, Delaware, Ohio.

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FOREWORD

Commercial hardwood forests occupy approximately 267 million acres in the United States of America. Of the many pests threatening this resource, insect borers are among the most important. Their damage ranges from degrading the value of timber managed for lumber and veneer to retarding regeneration efforts, damaging shelterbelts, and weakening or destroying shade, ornamental, fruit, and nut trees. Although the total value of this damage remains unknown, borers produce log degrade alone worth hundreds of millions of dollars.

A research coordination meeting, summarized in these Proceedings, was sponsored by the Washington Office-Forest Insect and Disease Research Staff, March 30-31, 1976, in Delaware, Ohio, to review the status of the current research program on hardwood borers and discuss its future direction and scope. Representatives from insect research, economics and marketing research, timber management research, utilization research, insect and disease management, cooperative forestry, and hardwood trade associations thoroughly discussed the borer research program and identified research and research implementation needs. Much of the information presented at the meeting and summarized in these Proceedings should be useful to researchers, research administrators, and user groups as interim working guides and state of knowledge summations.

Hardwood borer research is an integral part of the Forest Service's larger effort to efficiently, productively, and wisely manage the Nation's extensive hardwood resource. This meeting provided a responsible examination of the borer research program--a program that should, in the future, result in the development and application of specific survey and management strategies to minimize borer damage in a variety of hardwood stands managed for a number of different purposes.

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1/ This paper contains a significant amount of economic impact information.

CONTENTS

A HARDWOOD INDUSTRY'S VIEW OF INSECT BORERS

by

James L. Gundy[1/]

For the industry in Appalachia, I will present an unscientific study dealing with the relationship, crass though it may be, between profit and degrade in logs and lumber. Succinctly, the relationship is this--if a mill cannot retrieve sufficient upper grades of lumber from the logs it processes, the product may not be marketed at a profit.

A marketable product must be manufactured from the timber and logs purchased by a mill. Logs degraded by rot, fire damage, insects and disease are a major problem for the sawmiller, especially when the damage is not detected prior to processing.

To demonstrate why damage by borers--as well as other causes--reduces the market potential for timber, I want to briefly explain costs of production, return on sales by species and grade, distribution patterns, and markets.

The Cost of Production

The range of common experience in the cost of lumber manufacturing is between \$140 and \$180 per thousand board feet--an average of \$160. That figure breaks down this way--logging cost is \$60, processing cost is \$50, and stumpage is \$50. It is important to remember that this cost is constant--unaffected by demand and hence, unaffected by lumber prices.

The average rate of increase in production costs over the last 5 years has been just over 5 percent. For many years, the largest annual increase was in labor costs, but for the last year a major increase has been in stumpage prices. Equipment maintenance and replacement, manpower, taxes--all costs of doing business have increased. Our experiences are similar to those of the entire economy.

A major factor in analyzing our markets is the pattern of product distribution. The furniture industry consumes more than 53 percent of our total production and 99 percent of our production of FAS lumber. The pallet industry consumes 17 percent, railroad ties take about 10 percent, dimension and parts manufacturers take 7 percent, flooring uses 6 percent, mine and industrial timbers consume another 5 percent, and architectural woodworking uses the remaining 1 percent or less. These figures do not include residue distribution.

Easily, our prime market is the furniture industry with its heavy demand for lumber--especially in the profit-producing top grades. The furniture

1/ Executive Vice President, Appalachian Hardwood Manufacturers, Inc., High Point, North Carolina.

people turned, sawed, and hacked up more than 2 billion board feet of forest products last year.

Our mills keep a very close watch on the furniture industry. Our fortunes rise and fall with the manufacturers of home furnishings. Interestingly, the furniture people keep as close a watch on the home building industry. They are convinced that the sale of furniture is directly related to housing completions and new home occupancy.

From a high in the last quarter of 1973, the housing market started a downslide that ended in the third quarter of 1975--or thereabouts--no one is quite sure whether or not we are moving ahead. At its deepest point, the housing downturn was the worst since before WW II. Since the furniture people regard housing as a prime factor in sales, this downturn had a strong psychological effect on the market. My own personal opinion is that more aggressive sales efforts would have produced better sales. Furniture plants stopped purchasing materials of all kinds in early 1974. In fact, much of the lumber selling during most of 1975 was between furniture plants.

Late last year--about October--demand began a modest increase. Today--with many furniture plants working overtime--the demand for lumber is quite good.

Oak is the most used hardwood but furniture grade white pine is the leader in total construction. Of the 10 best selling bedroom groups in the country, three are pine and three are oak. Of the 10 best selling dining rooms, one is pine and three are oak. The list of second 10 best sellers in both categories is heavy in pine, maple, and painted finishes.

I give you this background because, again, it emphasizes our need for the higher grades of lumber. To make a profit, a sawmill MUST be able to produce enough furniture grade lumber to offset the loss he suffers in producing and selling the lower grades. And, traditionally, hardwood sawmills produce much more low than high grade boards.

The Return

It is obvious that return on investment in a sawmill is directly dependent upon the grade yield that can be achieved. First log grades yield our members 75 percent 1 common and better lumber. Second log grades yield about 55 percent of the top grades; third log grades produce 35 percent common and better; and the lowest log grades return less than 10 percent of 1 common or better lumber.

In Figure 1, we show the price history of our bellwether species--four-quarter plain white oak. We show three grades--FAS, 1 common, and 2 common. Between January 1970 and January 1976, the price for FAS has risen from \$235 to \$375--an increase of 59 percent and well above the break-even point. The price for 1 common has risen 31 percent, from

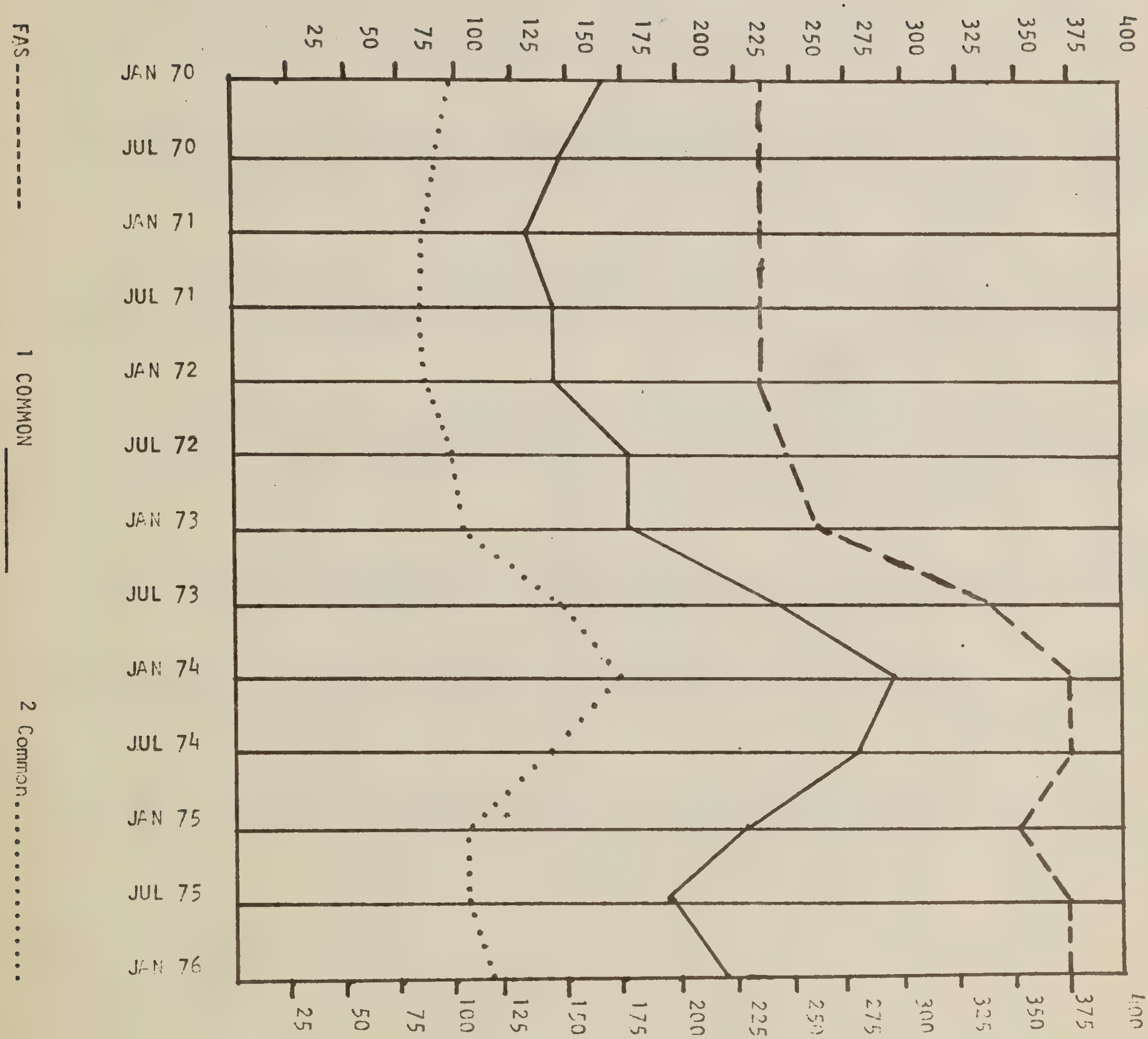

Figure 1.--Price history of four-quarter plain white oak.

$167 to $220. Still above the breakpoint but very close. The 2 common lumber rose from $98 in 1970 to $120 in 1976, an increase of 23 percent that returns only two-thirds the cost of production.

Also included in our prepared paper are tables taken from FPL-63, Hardwood Log Grades for Standard Lumber. These studies reinforce our experience in lumber yield by grade from the various log grades. For instance, Table 1 indicates that from an 18 inch, first grade white oak log the yield is 39.2 percent FAS, 3.5 select, 18.6 in 1 common, 13.4 in 2 common, 10.6 percent in 3A, and 14.7 in 3B. In a grade 2 log (Table 2) the yield is 7.1 percent FAS, 5.2 select, 33.5 number 1 common, 17.3 percent 2 common, 3.1 sound wormy, 11 percent 3A, and 20.4 percent 3B.

The third grade logs (Table 3)--and once again remember--the cost of production is the same for all grades--yielded 3.9 percent both FAS and select, 21.4 percent 1 common, 25 percent 2 common, 18.7 3A, and 27.1 percent 3B.

So--what I've attempted to show is that the lower the log grade the less top grade lumber is produced; top grades produce the profit in our present market system--hence sawmills may not make a profit by processing any quantity of degraded logs.

I am not able to produce figures showing the extent that hardwood borers degrade timber and logs. However, we know that boring insects do cost the timber owner in the stumpage prices he can command, and, the sawmiller in lumber grade yield and profit.

Unless the sawmiller has a superb market for chips, bark, and dust, he simply cannot afford to purchase degraded logs or timber under the present lumber demand structure and distribution pattern.

Research to find means of curbing hardwood borers, we feel, would be well worth the time and expense expended by the USDA-Forest Service and private enterprise.

Considering that demand for furniture--grade lumber is expected to increase by 40 percent by year 2000, we would classify borer control and research on other damaging factors imperative.

Table 1.--White Oak (Upland), Log Grade 1--Lumber grade yield by diameter

No. of Logs	DIB	Scale: Int. 1/4 Inch Gross	Net	Over-run	Scale: Scrib. Dec. C. Gross	Net	Over-run	Lumber Tally	NHLA Lumber Grade Yields (Actual): FAS	Sel	1C	2C	SW	3A	3B	Tmbrs. and SSE
	In.	Bd. ft.	Bd. ft.	Pct.	Bd. ft.	Bd. ft.	Pct.	Bd. ft.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
9	13	770	746	8.3	650	630	28.3	808	15.4	16.2	23.9	13.1	----	5.7	25.7	----
6	14	540	540	-4.1	480	480	7.9	518	18.9	4.3	28.8	19.1	----	10.8	18.1	----
5	15	585	574	-6.3	540	530	1.5	538	25.6	12.3	20.3	14.3	1.7	6.3	19.5	----
12	16	1,790	1,757	3.2	1,620	1,590	14.0	1,813	34.4	10.8	27.2	9.8	----	5.8	10.9	1.1
7	17	1,030	1,028	-1.4	960	958	8.8	1,042	29.1	9.2	32.3	4.5	----	3.7	12.0	9.2
4	18	650	622	10.6	610	584	17.8	688	39.2	3.5	18.6	13.4	----	10.6	14.7	----
1	19	190	167	34.7	180	158	42.4	225	13.3	----	36.0	22.2	----	----	28.5	----
8	20	1,655	1,616	2.8	1,630	1,592	4.4	1,662	29.7	4.2	36.5	9.5	.4	7.9	11.8	----
14	21	3,350	3,311	3.0	3,250	3,212	6.1	3,409	43.2	8.6	25.6	9.8	.6	4.3	7.9	----
8	22	2,080	2,073	3.7	2,000	1,993	7.9	2,150	36.4	10.4	29.6	7.0	1.6	3.1	10.2	1.7
7	23	1,870	1,857	2.3	1,840	1,827	4.0	1,900	58.8	6.4	16.4	5.3	1.0	5.7	6.4	----
3	24	1,045	1,019	-8.9	1,000	975	-4.8	928	40.5	6.0	30.2	8.9	----	5.4	4.4	4.6
5	25	1,760	1,738	.9	1,770	1,748	.3	1,753	49.0	5.4	19.6	10.9	----	5.2	9.9	----

Distribution by thickness of Log Grade 1 yields

Lumber Thickness	FAS	Sel	1C	2C	SW	3A	3B	Tmbrs. and SSE
In.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
4/4 & below	44.7	39.4	49.9	59.0	78.4	59.6	44.2	----
5/4	6.0	7.1	13.3	4.1	----	1.2	----	----
6/4	33.7	40.3	28.5	21.7	21.6	15.0	5.1	----
7/4	.2	----	.4	7.3	----	18.8	39.8	----
8/4 & above	15.4	13.2	7.9	7.9	----	5.4	10.9	----
Tmbrs. & SSE	----	----	----	----	----	----	----	100.0
Total lumber (Bd. ft.)	6,689	1,392	4,541	1,665	88	946	1,918	195

Table 2.--White Oak (Upland), Log Grade 2--Lumber grade yield by diameter

No. of Logs	DIB	Scale: Int. 1/4 Inch Gross	Scale: Int. 1/4 Inch Net	Scale: Int. 1/4 Inch Over-run	Scale: Scrib. Dec. C. Gross	Scale: Scrib. Dec. C. Net	Scale: Scrib. Dec. C. Over-run	Lumber Tally	NHLA Lumber Grade Yields (Actual): FAS	Sel	1C	2C	SW	3A	3B	Tmbrs. and SSE
	In.	Bd. ft.	Bd. ft.	Pct.	Bd. ft.	Bd. ft.	Pct.	Bd. ft.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
7	10	315	308	-2.3	240	235	28.1	301	3.7	2.7	31.2	17.6	----	14.9	29.9	----
28	11	1,620	1,605	3.7	1,270	1,258	32.3	1,664	2.0	4.1	20.9	23.8	2.8	12.4	33.3	.7
46	12	3,185	3,040	.4	2,740	2,615	16.7	3,051	5.6	5.1	23.3	16.8	4.0	12.6	30.8	1.8
27	13	2,280	2,191	----	1,930	1,855	18.1	2,191	3.3	2.4	26.6	22.8	1.1	11.6	29.4	2.8
29	14	2,780	2,609	-2.1	2,440	2,290	11.5	2,554	4.4	5.6	25.8	16.6	3.1	12.5	29.5	2.5
32	15	3,800	3,707	-4.5	3,530	3,444	2.8	3,539	5.5	4.0	31.9	22.5	2.9	6.9	23.3	3.0
18	16	2,420	2,314	-.5	2,200	2,104	9.4	2,302	2.4	2.7	30.8	23.3	.6	6.4	30.3	3.5
26	17	3,765	3,600	2.2	3,470	3,318	10.8	3,678	6.8	4.3	40.7	19.5	.2	7.8	15.8	4.9
19	18	3,410	3,281	-.5	3,190	3,069	6.4	3,266	7.1	5.2	33.5	17.3	3.1	11.0	20.4	2.4
15	19	2,920	2,851	8.3	2,760	2,695	14.6	3,088	5.5	3.0	42.1	27.0	.3	8.8	10.5	2.8
8	20	1,495	1,435	.9	1,500	1,440	.6	1,448	11.7	5.7	35.8	25.8	.6	9.7	7.4	3.3
3	21	670	649	9.4	650	630	12.7	710	23.8	2.7	30.4	20.1	----	6.2	10.0	6.8
5	22	1,120	1,099	-8.1	1,090	1,070	-5.6	1,010	13.9	3.7	41.1	6.2	7.6	5.3	18.8	3.4
3	23	805	736	-3.0	790	722	-1.1	714	5.6	1.5	48.3	24.7	----	7.6	12.3	----
2	24	565	555	8.3	550	540	11.3	601	16.0	4.2	47.7	15.3	----	7.2	9.6	----
1	25	220	215	-19.5	230	225	-23.1	173	----	----	30.1	31.8	----	7.5	30.6	----
--	26	-----	-----	----	-----	-----	----	-----	----	----	----	----	----	----	----	----
3	27	1,270	1,255	-15.1	1,300	1,285	-17.0	1,066	5.2	1.3	47.5	20.8	11.2	2.9	11.1	----
1	28	280	280	-9.3	290	290	-12.4	254	51.6	3.9	22.8	7.9	----	----	4.3	9.5

Distribution by thickness of Log Grade 2 yields

Lumber Thickness	FAS	Sel	1C	2C	SW	3A	3B	Tmbrs. and SSE
In.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
4/4 & below	51.8	54.1	57.9	64.1	72.7	60.8	45.5	----
5/4	.6	1.0	1.4	.7	2.8	.9	.1	----
6/4	42.3	34.1	35.2	21.2	13.7	6.5	5.3	----
7/4	----	1.6	.8	4.9	1.8	18.7	37.3	----
8/4 & above	5.3	9.2	4.7	9.1	9.0	13.1	11.8	----
Tmbrs. & SSE	----	----	----	----	----	----	----	100.0
Total lumber (Bd. ft.)	2,101	1,254	10,520	6,480	712	2,895	6,769	879

Table 3.--White Oak (Upland), Log Grade 3--Lumber grade yield by diameter

No. of Logs	DIB	Scale: Int. 1/4 Inch: Gross	Int. 1/4 Inch: Net	Int. 1/4 Inch: Over-run	Scrib. Dec. C.: Gross	Scrib. Dec. C.: Net	Scrib. Dec. C.: Over-run	Lumber Tally	NHLA Lumber Grade Yields (Actual): FAS	Sel	1C	2C	SW	3A	3B	Tmbrs and SSE
	In.	Bd. ft.	Bd. ft.	Pct.	Bd. ft.	Bd. ft.	Pct.	Bd. ft.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
4	8	95	87	34.5	70	64	82.8	117	----	----	2.5	13.7	----	4.3	79.5	----
20	9	675	656	10.4	580	564	28.4	724	.6	----	7.6	18.1	2.6	16.7	54.4	----
22	10	910	862	-.2	720	682	26.1	860	----	----	7.9	16.3	8.6	11.9	53.3	2.0
23	11	1,100	1,049	-3.2	870	830	22.3	1,015	----	.5	11.3	19.7	3.5	12.0	50.9	2.1
23	12	1,395	1,319	-2.1	1,210	1,144	12.8	1,291	1.5	----	7.7	22.9	2.1	9.9	47.6	8.3
17	13	1,325	1,263	-7.5	1,120	1,068	9.4	1,168	----	----	8.0	20.5	5.9	7.3	55.6	2.7
9	14	805	782	2.7	710	690	16.4	803	1.6	1.7	14.1	24.7	----	10.6	42.1	5.2
14	15	1,605	1,535	-3.1	1,470	1,406	5.8	1,488	.9	1.7	15.3	25.6	4.8	13.4	33.5	4.8
11	16	1,445	1,412	.1	1,310	1,280	10.4	1,413	----	.7	18.0	27.8	5.6	15.3	24.1	8.5
2	17	275	275	11.6	260	260	18.1	307	----	----	23.8	39.1	----	12.4	24.7	----
7	18	1,310	1,278	3.4	1,220	1,190	11.0	1,321	3.9	3.9	21.4	25.0	----	18.7	27.1	----
3	19	570	542	-3.5	540	513	1.9	523	----	----	26.4	37.8	----	11.5	24.3	----
4	20	775	744	-1.3	750	720	1.9	734	----	3.5	28.2	35.8	----	14.3	18.2	----
1	21	280	280	23.9	270	270	28.5	347	4.0	4.0	45.2	46.8	----	----	----	----
2	22	565	565	-6.9	540	540	-2.6	526	12.2	8.2	53.4	16.9	----	5.5	3.8	----
--	23	-----	-----	----	-----	-----	----	-----	----	----	----	----	----	----	----	----
1	24	205	205	-3.4	210	210	-5.7	198	3.5	8.1	20.7	34.3	----	6.6	26.8	----
2	25	680	680	-.1	690	690	-1.6	679	6.9	2.5	46.4	22.2	1.5	4.0	16.5	----
1	26	370	370	-30.5	370	370	-30.5	257	----	----	----	8.9	52.9	6.3	31.9	----

Distribution by thickness of Log Grade 3 yields

Lumber Thickness	FAS	Sel	1C	2C	SW	3A	3B	Tmbrs. and SSE
In.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
4/4 & below	68.7	47.0	68.2	66.9	91.9	66.5	47.9	----
5/4	10.7	11.7	4.4	1.2	1.9	2.3	.3	----
6/4	20.6	41.3	22.1	18.9	----	5.5	3.7	----
7/4	----	----	4.3	7.9	----	10.6	36.7	----
8/4 & above	----	----	.4	5.1	6.2	15.1	11.4	----
Tmbrs. & SSE	----	----	----	----	----	----	----	100.0
Total lumber (Bd. ft.)	233	223	2,522	3,398	521	1,599	4,867	408

COOPERATIVE FORESTRY LOOKS AT THE IMPACT OF HARDWOOD BORERS

by

Eldon M. Estep[1/]

In Cooperative Forestry, our orientation is toward the private sector. I submit that Cooperative Forestry's interest in the subject of this meeting is particularly relevant in view of the fact that about 70 percent of the nation's hardwood inventory is located on farm and miscellaneous private lands held by several million individual owners. We are concerned primarily with forest management as practiced by these private nonindustrial woodland owners and with forest products utilization from the standpoint of the logger, wood processor, and user of wood products. Hardwood borers unquestionably impact these principal programs of forest management and forest products utilization, and Cooperative Forestry has a stake in seeing that the negative impacts of hardwood borers are minimized. With this in mind, I would like to quickly review these impacts from the Cooperative Forestry position.

From a forest management point of view, the bud, twig, and stem borers are seen as a critical, much overlooked area of hardwood borer research. These insects cause degrade by forking and low branching and cause much of the poor form associated with second growth hardwood stands. Borers also have an impact on which young trees become established, which species, and in what numbers.

These problems mean that hardwood forest management and the landowner have been dealt a heavy blow by hardwood borers. The trees growing in his woodlot probably are not the species the landowner would have preferred and that might have become established there if borers had not been present. The numbers of trees and their growth rate have been reduced by borer action. The form of mature hardwoods available for harvest is far from desirable, largely as a result of borers.

The apparent quality and value of trees the landowner has for harvest may be just a dream, however. As the trees are felled and logs are bucked and milled, further ravages of hardwood borers will undoubtedly be exposed--defects in the wood that limit use and lower value. Industry experience and research have amply demonstrated the dimensions of such degrade due to holes, stain, and decay. The losses in hardwood volume, utility, and value are staggering. The combined effect of these losses on raw material supplies and prices will be increasingly unacceptable in the future.

1/ Forest Utilization Specialist, Cooperative Forestry Staff, USDA-Forest Service, Washington, D.C.

At a time when the private landowner needs all the technical and economic incentives available to encourage him to manage his timber, impacts of past hardwood borer action have already limited his options for management and utilization as well as his financial rewards for growing hardwood timber. The hardwood borers negatively impact stumpage prices received by small private landowners. Anything that decreases stumpage prices and overall economic returns received by the landowner works against our need to get more and better forest management into practice.

Similarly, volume and value losses caused by hardwood borers will be important limitations on future hardwood supplies and prices. Hardwoods are needed and expected to account for increasing proportions of our overall wood use in the decades ahead.

NATURE AND EXTENT OF BORER PROBLEMS IN BLACK WALNUT

by

Barbara C. Weber[1/]

Black walnut, Juglans nigra L., is an extremely valuable tree, commanding prices up to $5 and $6 per board foot of veneer quality timber. The source of black walnut timber has generally been farm woodlots where the trees were wild and scattered among other species. Often there was no management of the trees. However, this situation is changing rapidly. Black walnut plantations are being established and managed intensively to produce high quality timber and veneer. Breeding experiments with genetically superior strains should, within a few years, produce "super" trees for general distribution.

The insect and disease problems of "monocultured" crops (corn, wheat, soybeans) are well known in agriculture. Thus, problems were expected in the monocultures established in black walnut plantations although only within the past few years has serious attention been paid to the nature and scope of the insect and disease problems of young, intensively managed plantations.

Discussions with State protection personnel, lumber companies, and others implicate bud borers in very young trees as a major problem. Little is known about wood borers in black walnut, except they do not appear to be a problem in mature trees.

The primary concern of plantation managers is to grow a straight, high-quality tree as quickly as possible. This is achieved through management practices of weed control, thinning, pruning, and fertilization. However, concern is growing over the number and extent of forked trees in young managed plantations established on good to optimum sites. The forking was first attributed to frost damage, but later investigations showed the cause to be an insect boring into the newly expanding buds and shoots, thereby killing the bud. The causal insects were a complex of at least two--and possibly as many as five--species of Acrobasis caterpillars (Lepidoptera: Pyralidae).

The more important species are A. demotella Grote and A. juglandis LeBaron. Reports of damage to black walnut from one or both of these bud borers have been recorded from West Virginia to Kansas and from Michigan to Tennessee.

A. juglandis, commonly known as the pecan leaf casebearer, has been studied by Gill (1917). It has one generation per year. Larvae overwinter in hibernaculae in close association with lateral buds. When

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the buds begin to swell and expand in the spring, the larvae move and begin feeding at the base of the terminal buds. Feeding activity is concealed by a case constructed of silk and frass that surrounds the individual larvae. The damage at times is severe enough to kill the shoot. Older larvae move onto the underside of the rachis and feed on adjacent leaflets. Development is completed by late spring to early summer (Kearby 1976).

A. demotella also overwinters as larvae in hibernaculae near the base of terminal buds. In spring when walnut shoots expand, the larvae bore straight into the base of the buds. The larvae then turn upward from the base and eventually hollow out the entire bud. This type of feeding is usually fatal to the bud (Martinat 1975) and *A. demotella* is the major cause of stem deformity and height suppression in walnut trees on good growing sites in Missouri (Kearby 1976).

Black walnut exhibits poor apical dominance; thus, when the terminal bud is lost, several lateral buds are released, none of which becomes completely dominant. Unless one is pruned off so the other can reestablish a dominant terminal bud, the tree may remain forked throughout its life.

Kearby (1976) has attempted to establish the economic importance of the *Acrobasis* bud borers in Missouri black walnut plantations, but insect-induced deformities of trees on better sites are difficult to assess because so many species of insects feed on buds and shoots. Often, damage in any one year is less than 5 percent of an entire plantation, and the same trees do not appear to be attacked every year. Over an extended time period, however, this will amount to considerable damage. If a crop is still to be taken from the affected trees, considerable time and expense must be channeled into corrective pruning measures.

Individual tree vigor appears to affect the amount of damage caused by bud borers. Vigorous trees that show rapid shoot elongation are exposed to damage for shorter periods of time than less vigorous trees with slowly expanding shoots. Genetics is probably as important a factor as the quality of the site and available nutrients.

By the time the plantation trees reach a certain age and height, bud borer problems seem to diminish. Although not definitely established, the amount of crown closure appears to affect susceptibility to borers. This means that closer spacing of trees will result in an earlier closure of the plantation--hence, fewer forking problems due to the *Acrobasis* bud borers.

Another insect that has the potential for becoming a serious problem in black walnut plantations is an ambrosia beetle, *Xylosandrus germanus* (Bland.). This insect was first reported from black walnut in 1971 (Miller 1971) when it was collected from dying young plantation trees in southern Illinois. Subsequent investigations showed that a dieback problem in several plantations may have been caused by a disease-insect

association between two species of *Fusarium* and *X. germanus*. Kessler (1974) hypothesized that *X. germanus* may be carrying pathogenic organisms into apparently healthy trees. This beetle has already been found to be a vector of Dutch elm disease.

Little is known about the life history and ecology of *X. germanus* in the United States. It is an insect introduced from the Orient where it is damaging pest on tea plants. In Germany it has been implicated in the death of healthy young oak trees. The often-repeated debate arises as to whether the trees were actually healthy before the beetle attack or were, in fact, declining prior to beetle attack. Undoubtedly, "stress" plays an important role in determining the success of attack by these beetles. However, what constitutes stress has not been defined, nor has it been definitely established that the ambrosia beetles are introducing pathogenic organisms into black walnut trees.

Because *X. germanus* is imported, it may lack many of the controls that checked populations in its native country. If these controls are lacking, and if walnut is a preferred host, then more problems can be expected from this insect.

Both species of borers will have an economic impact unless proper control measures are found. Young trees may die or be deformed, with resulting loss of their potential long-term value. Land managers may also be discouraged from planting and managing black walnut for timber if they feel their considerable efforts will be in vain.

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NATURE AND EXTENT OF IMPACTS BY WOOD BORERS IN THE NORTHEAST

by

David E. Donley[1/]

For our discussion, wood borers are those insects that bore into living trees. Most of these insects are immature forms belonging to three pest groups, i.e., beetles, moths, and flies.

Wood borers have been recorded from every commercial species of hardwood tree. Forests containing these trees cover some 200 million acres of land in the continental United States. Forest types include oak-hickory, cherry-maple, oak-pine, northeastern northern hardwoods, and oak-pine-cypress forest types.

Research in wood borer impact in the Northeastern Forest Experiment Station area began in 1951 with a 19-mill study in Kentucky. Results of this early work indicated that oak borers were the most serious pests, with 88 percent of the oak logs studied showing some degree of damage. Borer holes were found in 73 percent of the oak boards studied. Other hardwood tree species found with borer damage were: yellow-poplar, hickory, basswood, beech, sugar maple, and black gum. However, the non-oak species were much less damaged than the oaks: black, chestnut, white, red, and scarlet.

More recently, in 1970, we began a series of impact studies to determine relative importance of borers to our white oak resource. In 1971, results of cooperative work with the cooperage industry showed that six borer species were damaging high value white oaks. Losses from these pests, in form of wood purchased and then rejected as unfit for staves, were about 10 percent. This loss estimate includes, in descending order of importance, damage by the white oak borer, the oak timberworm, the red oak borer, *Agrilus acutipennis*, the carpenterworm, and the Columbian timber beetle. In 1974, we published results of a three-State (Ohio, West Virginia, and Kentucky) borer loss study of primary wood production with red, black, and scarlet oak. This research showed that wood borer losses in factory grade oak lumber average some $24 per M board feet of lumber produced. A complex of borers including the carpenterworm, the red oak borer, the oak timberworm and several minor species, produced a loss of about $.02 per board foot of lumber studied.

Using 2 cents a foot loss as a base line, we can estimate annual oak borer losses at some $60 to $120 million. We must realize, however, that borer loss estimates to date have been generated by forest conditions and borer population levels that existed some 10-50 years ago.

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In 1974, we began field studies of current borer populations interacting with trees growing under 1974 conditions that will yield lumber and borer loss estimates only when these trees are harvested.

IMPACT OF HARDWOOD BORERS ON GREAT PLAINS SHELTERBELTS

by

Mary Ellen Dix[1/]

Great Plains shelterbelts have many proven economic and esthetic values. However, hardwood borers can adversely affect windbreak structure and density with concommitant losses in economic and esthetic benefits. The current impact of hardwood borers on Great Plains shelterbelts is difficult to assess because the extent of borer infestation has not been determined and the influence of infestation level on shelterbelt effectiveness has not been studied. I intend to present data from northern Great Plains research to show that borers represent potentially serious impacts on hardwood shelterbelts.

In 1934, the Prairie States Forestry Project (PSFP) was established to relieve and rehabilitate the drought-stricken Great Plains. Between 1935 and 1942, the United States Forest Service, under the PSFP, attempted to relieve and rehabilitate the Great Plains by planting 200 million trees and shrubs in 18,600 miles of field windbreaks from North Dakota to Texas (Van Haverbeke 1969, 1973). Since 1942, the U.S. Department of Agriculture Soil Conservation Service (SCS) has been responsible for shelterbelt establishment.

Shelterbelts are single or multiple rows of trees and/or shrubs planted to protect field crops, homesteads, livestock, and public facilities. Within the sheltered zone on the leeward side of the windbreak, windspeed is reduced and this causes important changes in air temperature, atmospheric humidity, soil moisture, evaporation, and plant transpiration.

The amount and extent of wind reduction depends upon the tree height, tree density, and continuity of the tree barrier. The distance that protection extends to leeward is proportional to windbreak height. Dense windbreaks reduce windspeeds more than open ones. Damaged or dead trees may leave gaps in the shelterbelt and reduce its effectiveness (Read 1964).

American agriculture is based on land as a reusable resource. If the top soil blows away, as is occurring in southwestern Kansas, the land becomes less and less capable of high level crop production. Shelterbelts protect cultivated fields by reducing soil erosion and by improving the distribution of snow and soil moisture. Crop yields usually show a net increase due to shelterbelt protection. In a Nebraska study, corn yields average 19 percent greater in a leeward zone 2 to 10 times the windbreak's height; in North and South Dakota, yields of rye, barley, and oats increased by 36 to 74 bushels per acre in a leeward zone 14 times the shelterbelt's height (Stoeckeler 1962). In Saskatchewan,

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wheat yields increased by 0.7 bushels per acre (Staple and Lehane 1955). Shelterbelts also reduce livestock mortality during blizzards, provide summer shade, and supply food and cover for wildlife (Read 1964). A farmstead windbreak, depending upon its size and design, can reduce fuel costs for house heating by 25 to 40 percent (Bates 1945). It also controls snow drifting and protects sensitive garden and orchard crops. In urban areas, properly planted shelterbelts commonly reduce road noises by 5 to 8 decibels (Van Haverbeke and Cook 1972).

Hardwood shelterbelts have been planted in all the Great Plains States. These belts, which are often monocultures, are ideal insect habitats. Ash borer or carpenterworm was found in more than 50 percent of the North Dakota shelterbelts surveyed in 1972 by our laboratory and State and Private Forestry, Region 1. Eleven percent of the green ash trees examined were infested and 3.3 percent were either completely dead or had died back and resprouted. In extreme western North Dakota, 29 percent of the trees contained borers and 11.5 percent were either completely dead or had died back (Tunnock and Tagestad 1972). The borers, by structurally weakening or killing the individual trees, alter the shape and continuity of the shelterbelt and reduce its overall effectiveness.

Green ash is one of the most common hardwood trees in North Dakota's 46,000 miles of shelterbelts. In Bottineau County North Dakota, the SCS estimates that it costs $1.80 to establish each green ash tree or $475 for a half mile, single row belt of 264 trees. This cost includes cultivation, a herbicide treatment prior to planting, and herbicide treatments for 3 years following planting. It does not include subsequent cultivation or management practices performed by the farmer or the cost of replacing dead trees. The Federal government, through a cost-sharing program administered by the SCS, pays 75 percent of the local cost of establishing each farm shelterbelt. At normal North Dakota growth rates, the green ash shelterbelts reach maximum effectiveness by the tenth year (personal communication with Don Boardman, S.C.S., and John Kringle, Assistant County Agent, Bottineau County, North Dakota).

If 11 percent of the 264 green ash trees in a single row, ½-mile belt in western North Dakota die because of borer infestation, the government and farmer will lose $52 of their initial investment in each belt plus an undetermined loss in total shelterbelt effectiveness. Although shelterbelts are relatively expensive to establish and require several years to reach maximum effectiveness; they provide substantial economic and esthetic benefits to the Great Plains region. If the impact of borer infestations in western North Dakota can be projected throughout much of the rest of the Great Plains, techniques for estimating infestation levels, along with effective, safe control measures are urgently needed. We plan to develop methods of surveying for and controlling the borers. These are discussed in a second paper (pg. 32).

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NATURE AND EXTENT OF IMPACTS CAUSED BY HARDWOOD BORERS IN THE SOUTHERN AND SOUTHEASTERN UNITED STATES

by

J. D. Solomon[1/]

Insect borers are among the most important pests of hardwood trees throughout the U.S. and southern Canada. Their mines and tunnels in the trunks, branches, and roots (1) cause defects (worm holes, bark pockets, and associated stain and decay) that seriously reduce the value of timber managed for lumber, veneer, and other wood products, (2) create problems in nurseries such as graft failure and breakage, weakened stems and rootstocks, and unsalable stock, (3) adversely affect tree form in regeneration, particularly in young plantations, (4) weaken and contribute to mortality in shelterbelt plantings, (5) destroy or reduce the esthetic value of shade and ornamental trees, (6) hinder the establishment and maintenance of hardwood seed orchards, and (7) cause damage resulting in decline and mortality in fruit and nut trees.

Studies have either been completed or are in progress at the Southern Station to measure borer impacts in the first three categories (sawtimber, nurseries, and plantations). No attempt has been made to estimate impacts in categories 4-7, even though they may be substantial.

Economically, the insect borers cause more measurable dollar loss (defect and degrade) in timber stands than any other group of hardwood insects. Over the years, several reports on borer damage have been published by such authorities as Hopkins, Putnam, Lockard, Carpenter, Harrar, Craighead, and Beal. Bryan (1958, 1960) studied the overall losses from various defects in southeastern Piedmont hardwoods and concluded that, exclusive of growth defects, the most common source of hardwood defect was insect borers. In Kentucky, Hay and Wootten (1955) found insect damage in 88 percent of the oak logs and 53 percent of the logs of other hardwood species. Similarly, Ebel (1967) reported that 25-47 percent of the log ends of several species of oak showed insect-caused defect.

Only in recent years have formal studies permitted the placing of dollar values on insect borer losses. Morris was among the first to place a dollar value on these losses. He (1957) sampled logs from three bottomland oak species (overcup, Nuttall, and willow oaks) and found a loss of $21.90 per M board feet. In 1964, he examined logs of three upland oaks (northern red, black, and post oaks) and combined the six oak species for an average loss of $20 per M board feet. On this basis, he estimated the loss at $60 million in 3 billion board feet of oaks sawn annually in the South. More recently, additional mill studies including

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three other oak species (water, cherrybark, and southern red oaks) have been conducted. In combining figures from these studies, degrade losses determined for 31 groups of logs cut from 9 oak species taken from 17 sites in 4 States averaged $20.65 per M board feet (Mossir' ms. in preparation). Based on these studies, insect borers are destroying about 15 percent of the value of southern oak lumber. By making the assumption that the average loss of $20.65 is representative of the oak component throughout the Southeast, and then applying it to the annual cut of oaks, we can derive a loss estimate. The latest available annual cut (oak lumber) figure is for 1972 when 1,907,280 M board feet were cut in the 13 southeastern States. Thus, the estimated annual loss in this region amounts to $39,475,332 or approximately $40 million a year. This estimate does not include borer losses in other regions or to other species, nor does it consider impacts in the other six categories listed above. Loss figures of $20.65 per M board feet and $40 million for the South compare favorably with recent estimates made in the Northeast. In 1974, Donley, Hay, and Galford assessed annual borer damage to the oaks in Ohio at $2-3 million. Donley (1974) reported an average loss of $24 per M board feet in the red oaks in the Northeast. He then estimated the loss in the red oak component at $50 million annually.

Several hardwood species are being planted under intensive culture in the South. Eastern cottonwood has received the greatest emphasis. Under ideal conditions, first-year growth up to 20 ft. can be expected. Moreover, pulpwood can be grown in less than 10 years, and sawtimber and veneer logs in 20 years. Cottonwood plantations on good sites, by age 28, should yield 29,450 board feet of sawtimber and veneer logs and 43 cords of pulpwood per acre. At current stumpage values of $60 per M for sawtimber and $5 per cord for pulpwood, the value would amount to $1,982/acre. The use of genetically improved planting stock now available is expected to shorten the rotation period by about 20 percent.

Approximately 50,000 acres of cottonwood have been planted in the lower Mississippi River Valley and new plantings of 5,000 acres per year are anticipated. Costs for establishing new plantations range from $150 to $200 per acre. Initial investments of this size almost demand protection from serious pests of which insects can be among the most important. Therefore, we have established studies to determine the impact of insects in cottonwood nurseries and plantations. Although these impact studies were designed to cover all the major insect pests of cottonwood, only the borers will be discussed here.

In nurseries, where the vegetative cuttings are produced for propagation, borers (particularly Paranthrene spp., Oberea spp., and Plectrodera sp.) cause sizable losses. The nursery operation produces wands which are bundled and sawn into 20-inch long cuttings. Borer-infested cuttings are culled and discarded. Most nurseries are planting 5 Stoneville Select Clones. A randomized complete block design was used for sampling. Plots consisted of 24 switches selected at random for each of the 5 clones for a total of 120 switches per replicate. There were 5 replicates giving a total of 600 switches per rootstock age group per nursery. Each switch

was marked off in 20-inch cutting lengths and then examined for borers to determine the proportion of cuttings infested. Field sampling has been completed in six nurseries in Mississippi and Louisiana. Although the data have not been analyzed, the proportion of culled cuttings (borer infested) ranged from 2 to 27 percent and averaged approximately 15 percent.

In young cottonwood plantations, the twig borer (Gypsonoma haimbachiana), the clearwing borers (Paranthrene spp.), Oberea spp., and other species commonly cause terminal die-back or stem breakage that affects both growth and tree form. An impact study to measure these losses was initiated in 1975 in first-year commercial plantations at two sites in Mississippi and one site in Louisiana. Briefly, at each site there are protected and unprotected plots replicated 10 times. The plots are visited periodically during the summer to assess the insect infestation. At the end of the growing season, the height and diameter are recorded and tree form is rated on a scale of 1-9. The study will run for 5 years or until the first thinning. First-year measurements and analyses have been completed for the Louisiana site. Height growth averaged 11.1 ft. in protected plots and 9.4 ft. in unprotected plots, yielding a significant difference of 1.65 ft. (a 15 percent loss in height growth). DBH averaged 0.96 inches in protected plots and 0.87 inches in unprotected plots, for a significant difference of 0.09 inches (a 9 percent loss in diameter growth). Tree form rating averaged 1.70 in the protected plots and a significantly greater 2.80 in the unprotected plots. This study will be continued for at least 5 years to determine whether these differences increase or decrease over time. Volumes will also be calculated when the study is terminated.

Another impact study will be established in 1976 to assess damage in older plantations. This study will pertain largely to borer damage from the poplar borer (Saperda calcarata), the cottonwood borer (Plectrodera scalator), and other species.

Summary

Nature and Extent of Impacts Caused by Hardwood Borers

Hardwood Resource

In 1970, there were about 267 million acres of commercial hardwood forests in the U.S.A. Ninety-five percent of this acreage was in the East and about 70 percent was located on farm and miscellaneous private lands held by several million individual owners. The total volume of hardwood growing stock is approximately 217 billion cubic feet--including 515 billion board feet of sawtimber of which one-third is comprised of "select" species where quality and/or surface appearance is an important consideration.

Insect borers are among the most important pests of hardwood trees. Their mines and tunnels in the trunks, branches, buds, and roots (1) cause defects that seriously degrade the value of timber managed for lumber and veneer; (2) create nursery problems such as weakened stems and graft failures; (3) adversely affect tree form in regeneration, especially in plantations; (4) weaken and contribute to mortality in shelterbelt plantings; (5) destroy or reduce the esthetic value of shade and ornamental trees; (6) hinder the establishment and maintenance of hardwood seed orchards; and (7) cause decline and mortality in fruit and nut trees. This meeting considered only the first four problems.

Lumber and Veneer Degrade

Success or failure in the hardwood lumber market is primarily determined by the yield of top grades of lumber. The Southern Forest Experiment Station has conducted several log degrade mill studies and has estimated an annual loss of approximately $40 million in 13 Southeastern States due to borer-caused oak log degrade. These figures are based on an average loss of $20.65 per M board feet, and an annual oak cut of 1.9 MM board feet. Similar studies at the Northeastern Forest Experiment Station determined an average loss of $24 per M board feet for red oaks in the Northeast. Researchers projected an annual loss in log degrade of some $60-120 million in the oak-hickory type of the Eastern United States. Another study showed that 4-16 percent of the white oak cooperage veneer purchased in a three-state area was rejected as wormy.

Plantation and Shelterbelt Problems

Borer impacts on stand establishment include problems with shelterbelts and intensive culture of black walnut and cottonwood. The total impact of borers on shelterbelts is unknown although limited studies indicate it is considerable.

In a 1972 survey, over 50 percent of North Dakota shelterbelts harbored either ash borers or carpenterworms. Eleven percent of the green ash was infested--representing a loss of $104 per row per mile on an initial

establishment investment of $950. Green ash is one of the trees commonly planted in the 46,000 miles of North Dakota shelterbelts.

Because intensive culture of black walnut is relatively recent, insect problems are not well understood. Stem borers do not seem to be a major problem in mature trees but bud borers in young trees are a serious problem. These borers may cause stem deformity and height suppression on 5-10 percent of a plantation's trees annually--a problem only partially overcome by expensive pruning measures.

Insect borers also cause serious problems in cottonwood plantations and nurseries. The impact of twig borers and clearwing borers is currently being studied. Results after one year indicate a height and diameter loss of 14 percent resulting largely from borer damage.

Nursery Problems

Borers cause sizable losses in cottonwood nurseries that plant valuable select clones. In these nurseries, vegetative cuttings are collected and sawn into uniform bundles. Borer-infested cuttings must be culled and discarded. The results of one impact survey at seven Mississippi and Louisiana nurseries indicate the proportion of culled borer-infested cuttings ranged from 1-23 percent and averaged approximately 12 percent.

CURRENT RESEARCH ON THE BORER PROBLEMS OF BLACK WALNUT

by

Barbara C. Weber[1/]

Two cooperative aid agreements are in progress to study the biology of the Acrobasis bud borers. These agreements are with William Kearby, University of Missouri, and Louis Wilson, Michigan State University. Kearby's emphasis is on the life history aspects; Wilson is concentrating on identifying the species complex, the predators and parasites, and some preliminary control tests using systemic insecticides. Other factors studied are geographic sites and growing conditions in relation to bud borer incidence, population fluctuations and overwintering mortality, and long-term impacts of bud borers on the growth and form of black walnut. These studies are very important from the economic standpoint because the high incidence of forked trees and the extra expense of corrective pruning may discourage land managers from establishing black walnut plantations.

Another study by Kearby and Al McGinnes of the University of Missouri is to determine the relationship between Acrobasis bud borers and the incidence of heartwood decay organisms. Preliminary results indicate that forked areas have a compartmentalization ("walling-off") of decay organisms caused by tunneling of bud borers. An insecticide test will be carried out by myself in southern Illinois; one of the target insects will be Acrobasis. The insecticides to be tested are the systemics Di-Syston and Temik, and the biological control agent, Bacillus thuringiensis.

I will also be undertaking a study on the bionomics of Xylosandrus germanus on black walnut and its effects on young plantation trees. Included in this study will be identification of pathogenic organisms possibly transmitted by the beetle; identification of ecological conditions that are a prerequisite for successful beetle attack; and a determination of the predators, parasites, or other factors that may influence Xylosandrus population fluctuations.

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DAMAGE FROM ONE GENERATION OF RED OAK BORER

by

David E. Donley[1/]

One of the biggest gaps in our understanding of the oak borer problem is the cost/benefit ratio obtained with a "control." To clarify this problem we can examine the effect of a single generation of the red oak borer on a stand of mixed oak.

Our study was established by plotting the location of every oak, to the nearest foot, on a 3.6 acre area. We measured each oak's d.b.h., basal area, and height to a 4-inch top (d.o.b.). Thus, for one generation of the red oak borer we located every insect attack on each tree and followed each attack with four examinations over the 2-year life cycle. The results may be seen in Table 1. We must now estimate the magnitude and distribution of these defects as they affect wood yield.

Obviously, the defects of this generation have had their greatest impact on wood already formed. Control of a given borer generation would immediately reduce this type of damage. However, an additional loss will be incurred when each of these defects must be overgrown to permit the trees to begin producing clear wood.

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Table 1.--Effect of one red oak borer generation on a mixed oak stand

	WO[1]	BO[2]	RO[3]	SO[4]	Total	Mean No. Annual Rings Damaged
No. of Trees	280	193	14	218	705	
Size of Defect:						
.5" X .5" X .25"	301	678	35	591	1600	2
2" X 1" X .5"	103	264	14	201	582	8
4" X 1" X 2"	30	95	6	68	199	16
6" X 1" X 2"	6	37	3	27	73	20

1/ White Oak
2/ Black Oak
3/ Red Oak
4/ Scarlet Oak

PHEROMONE RESEARCH ON CERAMBYCIDS

by

J. R. Galford[1]

Little or nothing is known about how long-horned beetles or cerambycids get together for mating. Except for a Russian scientist reporting that some males were attracted to a tethered female, there is no published information confirming a pheromone or sex attractant in this large family. Some researchers have reported that the species they studied did not seem to be aware of each other until they made antennal contact. Others contend that aggregation at flowers or on specific plants ensures sexual contact.

Last year, we initiated a study to determine if the red oak borer, Enaphalodes rufulus (Haldeman), has a sex or an aggregating pheromone. Our initial approach to the study was an attempt to attract males or females or both to various combinations of live virgin beetles. We also used slow release plastic capsules containing an extract from a Porapak column used to continuously collect volatile compounds of virgin males and females for 7 days. (I would like to thank Dr. John Peacock for his help in doing this.)

We used 21 traps coated with "Stickem" and placed them at heights ranging from 2 to ca. 15 meters. Our traps were freestanding, placed on fence posts, or suspended from a rope. None were attached directly to a host tree. We did not catch a single beetle indicating that the beetles probably do not have a long-range pheromone.

In the fall of 1975, we attempted to trap another cerambycid, the locust borer, Megacyllene robiniae (Forster), using virgin females and sticky traps. Although there were hundreds of adult borers in the area, we caught none. We then tethered females on different plants in the area. The females were checked two or three times a day to see if they were mating. Only females tied to locust trees or goldenrod flowers got mated. Females tied to aster flowers and other plants were never observed with a male.

Those results combined with other field observations indicated that the locust borers probably respond first to the host, then to some other factor. A purely visual or tactile response could not be ruled out, but we began to look for a short-range pheromone.

We started laboratory cultures of both the red oak borer and locust borer using artificial rearing media. We used the locust borer because we can rear it in ca. 2 months vs. 7-8 months for the red oak borer. Also, the locust borer is diurnal and the red oak borer is nocturnal.

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To date we have found that the locust borer and another cerambycid, the painted hickory borer, Megacyllene caryae (Gahan), have short-range pheromones. We have not completed all our tests, but we know that males respond to a chemical deposited by females on the tree. The pheromone alerts the male to the presence of the female and causes him to remain on the tree and search for her.

In our laboratory tests we recorded the time spent by a male on a stick of wood. We used five virgin females for each test and five sticks of wood placed on pegs in 10-gallon aquariums. One of the five sticks of wood had been exposed to five virgin females for 2 or more hours.

Initial visits to a stick of wood were entirely accidental. Visits to sticks unexposed to females usually lasted less than 1 minute while visits to a stick exposed to virgin females lasted from several minutes to several hours. Males on female-exposed bolts often made 20-50 extremely rapid trips up and down and around the stick. Their behavior was obviously different than the behavior of males on the check sticks.

We have tried the same tests on red oak borers but only in 2 of ca. 20 tests have we gotten a positive response. I feel that we have one or two problems. We either need a different bioassay technique, or our artificially reared red oak borers are producing little, if any, pheromone. Poor pheromone production has been a problem in other artificially reared insects and recent reports have indicated that many insects get their pheromones from their host.

In conclusion, I would like to say that if we eventually find a "tree-marking" pheromone in the red oak borer, it would have excellent potential for use as a confusant for the following reasons:

1. The adults occur only in odd-numbered years except in the Deep South.

2. The emergence period lasts only about 6 weeks.

3. The population of adults is probably never more than one to three dozen per acre.

4. The male emergence occurs 7-10 days ahead of the peak female emergence.

5. The existence of an even-year generation in extremely small numbers indicates that the borer population might remain suppressed if controlled over a large area.

Finally, a confusant might be used to "mop up" the beetles in an area where silvicultural control was applied.

CURRENT RESEARCH IN
RED OAK BORER SILVICULTURAL CONTROL

by

Charles R. Hepner[1/]

Since 1973 our research has been directed toward developing a silvicultural control for the red oak borer (Enaphalodes rufulus, Hald.). The aim of our control is to eliminate at least 50 percent of the offending borer population. To develop such a control, we had to know which trees were most likely to produce adult borers. We have established 12 test plots in southeastern Ohio. The 3 to 5 acre plots are even-aged, pole sized with site indices ranging from 40 to 80 within each plot. Such stands are typical mixed-oak types found in that area. We modified the plots by removing the few trees over 11 inches in diameter to simplify examination for borer attacks. All red, black scarlet, and white oaks were tagged and numbered. Individual tree measurements were d.b.h., stump circumference, and height. Borer populations were determined by visually examining portions of every oak. All trees less than 4" d.b.h. were examined to a height of 6 feet. All trees over 4" d.b.h. were examined to a height of 16 feet. Each tree has been checked four times in the first borer generation, between September 1973 and September 1975. Several plots have been diagrammed on rectangular coordinate paper with each tree being located to the nearest foot. The following tables will show the results of the collected field data from four plots designated as checks (untreated).

There were 1010 (23%) black oaks, 1477 (34%) scarlet oaks, 1589 (37%) white oaks, and 300 (6%) red oaks, for a total of 4376 trees (Table 1). In the 1973 borer generation, black oak produced 76 (44%) borers, scarlet oak 71 (41%) borers, white oak 15 (10%) borers, and red oaks 9 (5%) borers. Thus, black and scarlet oaks, with 57 percent of the trees, produced 85 percent of the adult population. White oaks, which made up 37 percent of the total number of trees, had relatively few exits. Red oaks, while producing few borers, also had the smallest number of trees. Knowing this relationship between tree species and borer exits, we next looked at the relationship between tree size and borer exits.

Table 1 shows the distribution of tree species by diameter class. Black and scarlet oaks from 4.1 to 8 inches in diameter represent 37 percent of the total number of trees in the plots. These trees become important when we see that they produced 73 percent of the borers (Table 2). To survey for trees to remove in red oak borer control in our plots, we would need to be concerned with only 1857 (scarlet and black oaks) from the total of 4376 trees. Adult borers developed in only 108 of the

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Table 1.--Number of oaks by diameter and species

Tree Species	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11+	Total
	Tree Diameter (inches) Classes												
Red	3	13	47	61	49	35	34	30	15	9	2	2	300
White	3	78	247	320	333	265	164	114	46	16	3	0	1589
Scarlet	8	49	101	166	227	245	256	183	140	76	24	2	1477
Black	1	12	35	48	151	177	200	163	115	72	33	3	1010
													4376

Table 2.--Red oak borer exits by tree diameter and species

Tree Species	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10+	Number of Infested Trees
	Tree Diameter (inches) Classes											
Red	0	0	0	0	1	1	4	1	2	0	0	9
White	0	0	0	1	5	7	2	0	0	0	0	15
Scarlet	0	0	0	7	14	24	13	9	3	1	0	71
Black	0	0	1	0	19	16	17	15	5	3	0	76

1857 4" to 9" diameter black and scarlet oaks. Removing those trees from our plots would, therefore, result in a 73 percent reduction in borer population, a reduction well over our goal of 50 percent. Using this information, we selectively removed host trees in eight study areas. The evaluation of these tes s will be completed in 1977.

BORER RESEARCH IN THE NORTHERN GREAT PLAINS

by

M. E. Dix and A. D. Tagestad[1/]

Since 1964, the Shelterbelt Laboratory has surveyed and identified the possible insect pests of the trees and shrubs in the northern Great Plains shelterbelts, native woodlands, and ornamental plantings. In 1972, a key to over 300 species was published (Stein and Kennedy 1972). Two Lepidoptera, the carpenterworm, Prionoxystus robiniae (Peck), and ash borer Podesesia syringae (Harris), are major pests of green ash, one of the few trees able to survive in the harsh climate of the Dakotas. In a 1972 survey of North Dakota shelterbelts, the carpenterworm and ash borer were present in 28 percent and 51 percent, respectively, of the surveyed belts (Tunnock and Tagestad 1972).

Methods must be developed to sample these borers, predict their populations and damage, and control their damage. Knowledge of their biology is essential to the development of any sampling or control program. Currently, we are studying the biology, behavioral chemicals, and chemical control of these insects.

Borer populations appear to increase during dry years. Possible correlations between periods of below average rainfall and infestation levels, damage, and tree death are being investigated by Arden Tagestad.

When possible, natural controlling agents of these borers are being identified. McKnight and Tunnock (1973) identified the braconid, Macrocentrus marginator (Nees), as a common parasite of ash borer in North Dakota. Last summer we found the icneumonid, Lissonota sp., parasitizing carpenterworm larvae.

In 1973 and 1974, two isomers of a carpenterworm attractant were tested in cooperation with R. Doolittle (ARS-Insect Attractants, Behavior and Basic Biology Research Lab). The Z, E, isomer of 3, 5-tetradecadien-1-ol acetate attracted male carpenterworm moths while the E, E, isomer attracted the male aspen carpenterworm, Acossus centerensis (Litner). Neither isomer greatly inhibited or synergized the response of males of either species to the other isomer. A paper on this study has been accepted by Environmental Entomology (Doolittle et al. 1976).

In 1975, the effect of attractant dispenser, trap color, and trap height on the P. robiniae catch size was tested in mixed hardwood stands of the Turtle Mountains in north-central North Dakota. Sticky cylinder-platform traps baited with one of five different dispensers containing 500 ug of Z, E-3, 5-tetradecadien-1-ol acetate were suspended from tree limbs 1.5 m above the ground and randomly distributed at least 0.8 km apart.

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A 10:1 volumetric ratio of the keeper, trioctanoin, was added to the attractant. The traps were checked every third day until the flight ended. Preliminary results indicate that the rubber band, plastic cap, and Magicap were more effective than the rubber stopper and cotton wick (Table 1). The cotton wick did not attract males after the ninth day. This test will be repeated in 1976 because both the trap location and the late trapping period may have affected the catch.

In a similar manner we tested seven trap colors from June 26 to July 24. The traps were rebaited each week. Trap color did not significantly affect the catch size (Table 2).

Carpenterworm traps baited with cotton wicks containing 500 ug of Z, E isomer were suspended in a tree 1.5, 3, 6, and 9 m above the ground in the manner described above. The traps were changed biweekly for 3 weeks. The number of *P. robinae* did not change with height (Table 3). In a similar test with *A. centerensis*, the number of males increased with height, but the difference between heights was not significant. Additional data will be obtained in 1976.

In 1973 and 1974, possible male ash borer attractants were screened at the Bowman Haley Dam in southwestern North Dakota and in the Turtle Mountains of north-central North Dakota in cooperation with D. Nielsen (Ohio Agricultural Research and Development Center). At Bowman, male *Podosesia syringae* were attracted to Z, Z-3, 13-octadecadien-1-ol acetate (ODDA). A different morphological form of the ash borer appeared in the Turtle Mountain traps. In 1975, in cooperation with D. Nielsen, we began a 2-year trap-out study at the Bowman Haley Dam. We are attempting to reduce the ash borer population in four selected belts using Z, E, isomer. Preliminary results are inconclusive.

In 1973 and 1974, 1 percent Lindane and 1 percent Dursban successfully controlled ash borers in three North Dakota shelterbelts. In 1974 and 1975, ¼ percent and ½ percent Lindane, Orthene, Thiodan, and Dursban were tested in five shelterbelts for both ash borer and carpenterworm control. Dursban (0.5 percent) and Lindane (0.5 percent) are currently registered for borer control in farm shelterbelts.

Future research plans include (1) cooperate with J. Solomon, R. Doolittle, and D. Nielsen in the development of techniques to survey and control hardwood borers using synthetic attractants, (2) complete scheduled insecticide trials, (3) complete the borer-drought study, (4) study the biology of the wood-boring moths and identify their natural controlling agents, and (5) initiate a study to relate borer populations and damage to shelterbelt effectiveness.

Table 1.--Effect of different dispensers on *Prionoxystus robiniae* catch during 1975 emergence season

Day of Catch	3	6	9	12	15	1-15
Dispenser[a]	No caught per dispenser					
Rubber band	74	79	10	6	2	171
Plastic cap	58	59	12	6	1	136
Magicap	62	41	12	7	0	122
Rubber stopper	26	25	7	6	0	64
Cotton wick	32	7	0	0	0	39

a) 5 replications

Table 2.--Effect of trap color on trap effectiveness during the 1975 season

Trap Color[a]	Males/trap	± SE
Grey	63.6	10.31
Speckled brown on white	60.8	20.46
Yellow	59.6	19.54
White	58.0	20.80
Speckled white on brown	48.5	17.04
Green	47.8	16.10
Red	44.6	15.93

a) 5 replications

Table 3.--Effect of trap height on trap catch

Height (meter)	*Prionoxystus robiniae*[a] (males/trap)	(± SE)	*Acossus centerensis*[b] (males/trap)	(± SE)
1.5	8.8	4.58	11.4	6.10
3.0	6.8	2.49	16.6	9.84
6.0	5.0	3.63	19.8	9.86
9.0	6.0	4.90	22.0	13.32

a) 8 replications

b) 5 replications

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AMBROSIA BEETLES, ESPECIALLY CORTHYLUS COLUMBIANUS, AND DEGRADATION IN HARDWOOD TREES AND LUMBER

by

F. L. Oliveria[1/]

Among the most successful wood-inhabiting beetles are the ambrosia beetles, well known as forest insects causing damage of great economic significance to trees and timber. Historically, this group of insects has been of major importance in freshly felled trees, green logs, dying trees, stumps, and sometimes in moist freshly sawn lumber. Most damage has occurred in logs. The intimate association of these beetles with specific fungi is of great interest, not only from the standpoint of economic entomology, but also with regard to the basic concepts of symbiosis.

Only one North American species, Columbian timber beetle (CTB), (*Corthylus columbianus* Hopkins), infests healthy living trees. Because the beetle attacks only vigorous living hosts (Anderson 1960) the active translocation of nutrients results in greater sapwood staining than is caused by other North American ambrosia beetles (Giese 1966). Even heavy population buildup in a single tree does not cause host mortality. Periodic invasions during the life of a tree are overgrown resulting in large volumes of degraded wood throughout the diameter of the trunk.

Pettinger and Giese (1963) reported population density was negatively and curvilinearly correlated with height of the host tree. Including trees exceeding 85 feet in height, 90 percent of the population was confined to the lowest 8 feet although attacks have been found as high as 29 feet from the soil surface. This makes it possible to salvage clean boards from upper logs, but the cost of sorting is often prohibitive.

Sawmillers and lumbermen have long been well acquainted with CTB damage in several species of hardwoods. They have applied many common names to the defect in lumber: "flag-worm," "worm-spot," "steamboats," "patch-worms," "grease-spots," and "black holes."

In lumber and veneer, the main objection to CTB damage is not the small gallery holes but the large associated blue-gray stains. Neither galleries nor stains affect structural strength of the lumber (Nord and McManus 1972), yet boards are degraded on this account. The cooperage manufacturer, however, is vitally concerned with both the gallery holes and the stain, especially in oak. One or two gallery holes may be sealed with wooden plugs and thus tolerated. A small number of "flags" are allowed in lower quality cooperage, but in high quality cooperage the extensive stained wood does not meet the requirements of tight cooperage

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(Wilson 1959). Independent Stave Company[2/] of Missouri has estimated that 20-30 percent of the white oak logs they buy are found to be infested with "flag-worm" when they are sawn. This is causing a stave loss of approximately 5-7 percent.

There are 18 known host species of CTB distributed among the following genera: Quercus, Fagus, Acer, Betula, Tilia, Liriodendron, Juglans, Nyssa, Platanus, Castanea, and Ulmus. These host species include some of the most economically important lumber species of the South and Central States. The CTB has been reported as far south as Georgia and Arkansas and as far north as Michigan and Massachusetts (Kabir and Giese 1966). Hopkins (1894) estimated that from half to three-fourths of the white oak (Quercus alba L.) and chestnut oak (Quercus prinus L.) in certain areas of West Virginia were affected by Columbian timber beetle.

Veneer manufacturers suffer heavy losses from "flag-worms" because these defects cannot be tolerated in face veneer. One veneer manufacturer in Kentucky[3/] estimated that about 30 percent of their logs bought for veneer at veneer prices had to be used for lumber (a lower value product) due to "worm hole" defects, primary among which are those caused by CTB. McCambridge and Kowal (1956) reported severe damage to yellow-poplar in Virginia and North Carolina, with an estimated 5 percent to 10 percent of the trees infested and with price reductions of about $105 to $65/M board feet imposed by the mill operators because of this defect. CTB has also been responsible for a 40 percent loss in timber value of yellow-poplar (Liriodendron tulipifera L.) throughout the Central States (Giese 1966).

Soft maple and white oak lumber containing CTB damage is put into a special grade, WHND (worm holes no defect); for No. 1 Common and better grades, southern WHND lumber sells for $35/M board feet less than CTB-free lumber which is classified WHAD (worm holes a defect), (Southern Hardwood Market Report, March 1976). Giese (1966) has reported that the Columbian timber beetle has been responsible for a 30-35 percent reduction in the value of soft maple timber in the Central States. Assuming a total cut of 200 million board feet in 1975, this loss amounted to $15,750,000 based on $225/M board feet for WHAD soft maple.

While a hardwood lumber grader must abide by rules set forth by the National Hardwood Lumber Association and downgrade a "flag-worm" riddled board, a cabinet maker, home builder, architect, or furniture designer may view the same board as a piece of wood having exceptional beauty. The extensive boat-shaped, blue-gray patterns produce a particularly beautiful effect when finished with such stains as cherry, lime oak, mahogany, green, etc. (Nord 1971).

2/ Personal correspondence with Mr. Boswell, Independent Stave Company, Lebanon, Missouri.

3/ Personal correspondence with Procurement Department, Wood-Mosaic Division of Olinkraft, Louisville, Kentucky.

The preponderance of wormy maple and other hardwoods with borer damage is making it necessary for designers and builders to use woods with these character grade defects in place of "clear" wood as in the past. Fine Hardwood-American Walnut Association[4/] stated that 8 out of 10 hardwood trees harvested fall into the class of character grade. In light of this situation they, in cooperation with Hardwood Plywood Manufacturers Association,[5/] are providing a series of showings for furniture designers that incorporate character grade veneers and plywood. They have selected red oak, white oak, walnut, ash, soft maple, cherry, and pecan-hickory as the demonstration species. This attempt to gain recognition for these woods from the furniture company designers as well as the independent designer may well result in a higher demand and subsequently higher prices for character grade woods. This effort is not only spurred by the possible financial gain but also many of the companies are no longer able to supply top-grade plywoods and veneers. Many of them have warehouses full of character grade woods.

The majority of the information concerning biology, population dynamics, and economic impact of CTB has resulted from work at Purdue University and the Southeastern Forest Experiment Station[6/]. Scientists at both locations found that the biology of the beetle was very similar in each segment of the population. The gallery was initiated by the male, mating took place in the gallery, the eggs were laid in vertical cradles, and the larvae fed on the yeast, Pichia. It is clear that the association of the Columbian timber beetle with the yeast is truly a symbiotic relationship. The beetle provides an overwintering site and serves as a mycetangial vector for the yeast, the tree serves as a substrate for both the beetle and the yeast, and the yeast supplies the food mass for the ambrosia beetle. Nord (1972) reported that the CTB population in Georgia had four generations per year as opposed to the three generations per year in Indiana as reported by Milne and Giese (1969). However, climatic variations would readily account for this difference. Scientists at Purdue collected CTB artifacts throughout the entire North American population range in an effort to map the extent of the population and to correlate various climatological data with fluctuations in population density (Oliveria and Giese 1976). An outline of the population range was determined and two fringe areas were located where the beetle is actively expanding its range. An excellent series of samples was collected depicting the spread of the CTB population up the Mississippi and Ohio Rivers.

The possibility of actually determining the nature and derivation of epiphytotics of the timber beetle throughout its range could greatly aid in the development of preventive and/or control measures.

4/ Personal correspondence with Mr. Gott, Fine Hardwoods-American Walnut Association, Chicago, Illinois.
5/ Personal correspondence with C. McDonald, Hardwood Plywood Manufacturers Association, Arlington, Virginia.
6/ The Forest Service has an active research project on Corthylus columbianus, the Columbian timber beetle, at the present time.

Before any control measures can be applied to the CTB, the biology and economic impact of the pest must be thoroughly understood. More work, especially in the areas of parasitism, predation, and impact, must be done before control or preventive measures can be meaningfully applied.

In the past, research work on CTB was limited almost exclusively to studying the biology and ecology of the beetle in its natural habitat. There have been no recorded evidences of parasites or predators associated with the larvae or the galleries. Milne and Giese (1969) found immature mites of the genus Leptus (Erythraeidae) occasionally clinging to dead and living adults. Several other insects including dipterous and coleopterous species have been reported in association with the galleries and the sap at the gallery entrance, but none appear to be CTB predators or parasites. Kabir and Giese (1966) also reported nematode associates.

The combined damage caused by CTB results in an economic value loss of timber for veneer, cooperage, and lumber. However, if the plywood and veneer industries successfully expand the existing market for character-grade woods, some of the economic impact will be lessened.

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STATUS OF CURRENT RESEARCH ON INSECT BORERS IN THE SOUTHERN AND SOUTHEASTERN UNITED STATES

by

J. D. Solomon[1/]

Insect borers are far less dramatic than defoliators and bark beetles in gaining public attention. This is understandable when one considers that both the borer larvae and their galleries are almost totally hidden from view during the entire growth of the tree. Therefore, very few people ever see either the borers or their damage--most are totally unaware of the problem. In timber production, only when the tree is cut and sawn into lumber and other products does the damage become evident, yet, the producer frequently still does not see the damage--only the mill operator. Thus, research on the borers has been badly neglected in favor of the more dramatic pests, in spite of the fact that borer-related losses far exceed those of most other groups.

Historically, early research and control efforts treated the borers primarily as pests of shade and ornamental trees. Only during comparatively recent years has the extent of borer damage in timber stands been recognized.

The insect borers are unique in that they spend most of their lives (sometimes years) hidden in deep galleries. Thus, they do not lend themselves readily to control by conventional means. Novel approaches to prevention and control demand familiarity with the insect. Therefore, present goals at Stoneville have been directed largely at developing means for recognizing and identifying the insect borers and their damage, elucidating their life and seasonal histories, assessing their natural controls, measuring impact, and developing controls.

Early work on the borers at Stoneville was initiated by Morris, but his research objectives also included the forest tent caterpillar and cottonwood insects. Similarly, Solomon now finds his research effort divided between borers and regeneration (primarily cottonwood) insects. Although Oliveria's efforts are directed largely toward the regeneration insects, he will also be concerned with some borer species particularly those causing damage in nurseries and plantations.

The carpenterworm and red oak borer are undoubtedly two of the most important species to the timber industry. Since the Delaware Lab chose to emphasize the red oak borer, we decided to focus on the carpenterworm. However, considerable effort has also been directed to the cerambycids, sesiids, and other groups of borers. A comprehensive knowledge of the carpenterworm has been developed, including information on rearing methods, larval development and instars, tunneling patterns, unpigmented

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mutant or strain, host preferences, emergence rhythms, mating habits, fecundity and oviposition behavior, longevity, sex ratios, stain and decay associated with galleries, light trapping, bark scar analysis, natural enemies, and direct controls.

Procedures for rearing sizable numbers of carpenterworms for research purposes have been developed in spite of their long life cycle and other hindrances. Forest rearing consists of planting either the eggs or young larvae in holes drilled in host trees (up to 200/tree) and confined by small screen cages. The cages are visited daily during the emergence period to collect the moths. The life cycle is 1 or 2 years and survival ranges from 60-70 percent. Laboratory rearing consists of culturing carpenterworms aseptically on an artificial diet in one-pint glass jars with modified ring-cap covers. A culture is held at 80° F. for the first 12 weeks, given a cold exposure for 12 weeks, then returned to 80° F. Following the cold exposure, the culture is inspected weekly for pupation. Jars containing pupae are segregated and inspected daily for adult emergence. Pupation and emergence occur largely between age 8-12 months. Survival ranges from 60-80 percent.

Instar numbers in the carpenterworm range from 8-14 in field-reared insects and 8-31 for those reared on artificial diets. Growth does not fit Dyars rule of geometrical progression, but rather increases at a decreasing rate through Instar 7, then levels off near a ratio of 1. These results together with observations of some of the sesiids suggest that a high and variable number of molts may be characteristic of the wood-boring Lepidoptera. Practically, only the first 4-6 instars can be determined by head width.

Seasonal and diurnal emergence rhythms elucidated for carpenterworm moths facilitate the field collection of moths, development of pheromone bioassays, and optimum timing of direct controls. Moth emergence begins in April, peaks in late May or early June, and ends in late June or early July. The average emergence period lasts 2½ months, but about 90 percent of the moths emerge within a 4- to 5-week period from mid-May to mid-June. Temperature summation provides a good prediction of seasonal emergence. Emergence begins, peaks, and ends when means of 610 $\pm$ 31, 1678 $\pm$ 54, and 2656 $\pm$ 81 day-degrees have occurred from January 1. The diurnal rhythm indicates that male emergence begins during early morning, peaks in late morning, and ends during early afternoon. Female emergence begins around noon, peaks during midafternoon, and ends before dark.

A study of mating behavior indicates that females begin calling at a mean age of 29 $\pm$ 11 minutes and mate at the mean age of 59 $\pm$ 21 minutes. The mean copulatory period for 129 pairs was 91 $\pm$ 51 minutes. Females mate only once while males are polygamous. Females exhibit an afternoon calling rhythm that typically begins at noon and ceases at nightfall or soon afterward. The male's response reaches a peak during midafternoon and ceases at nightfall regardless of whether the females continue to call.

Oviposition and fecundity studies indicate a nocturnal oviposition rhythm (a survival-enhancing factor) except for a brief period on the afternoon of emergence. The oviposition period averages 4.2 $\pm$ 1.5 days with 2/3 or more of the eggs deposited during the first day. Moths prefer rough bark species for oviposition. Two-year-old moths are more fecund than 1-year-old moths, and those reared from oaks are usually more prolific than those from elm and ash. Mean numbers of eggs deposited ranged from 331 for 1-year-old moths reared from American elm to 737 for 2-year-old moths from Nuttall oak. Moreover, in rearing and host preference studies, survival has been significantly greater from oak than from elm and ash. Thus, the high survival and fecundity of moths reared from oak help to explain why forest stands with a high proportion of oaks sustain the greatest damage.

The male:female ratio for 10 broods (19,310 moths) of forest-reared carpenterworms averaged 84.4:15.6 for moths developing in 1 year and 34.1:65.9 for those requiring 2 years. The combined sex ratio for the 10 broods averaged 59.1:40.9, or ca. 3 males to 2 females, a significant departure from an expected 50:50 ratio. The fact that the sex ratio fluctuated very little from year-to-year, lends support to past observations that natural carpenterworm populations are comparatively stable from year-to-year.

A preliminary study of stain and decay invading the wood around carpenterworm galleries (age 1 and 2 years) was assessed in three hardwood species. Stained wood was present around 100 percent of the galleries. Decay was visible around 60 percent of the galleries in Nuttall oak and 5 percent of the galleries in American elm. No decay was found around galleries in green ash. Since carpenterworm and other borer galleries may remain open for several years, borer galleries could be important entryways for stain and decay organisms.

Thirty species of cerambycids and sesiids, and several species of cossids, buprestids, pyralids, noctuids, olethreutids, and cephids have been reared from living southern hardwoods. Descriptions of their damage and knowledge of the biology, ecology, and natural control of the more important species have been or are being developed.

A frass key has been developed for identifying the cossid, sesiid, and cerambycid borers of southern hardwoods. Because of their hidden habits, ejected frass present at the entrance hole, in bark crevices, and on the ground below, provides a convenient means for identification. The feasibility of expanding the key to other regions should be explored.

An annotated bibliography has been compiled for the carpenterworm (w/Hay). Similarly, a bibliography on the sesiid borers (w/Dix) is almost complete. We should also consider one for the cerambycids.

A study on growth and yield being conducted by Bryce Schlaegel calls for the destructive sampling of 15 trees from each of 40 locations in the South. Disks are being taken at 5-foot intervals from stump height to

tree top for each tree. Before discarding, we are examining the disks for information on: (1) prevalence and relative importance of the various borer species, (2) pattern of borer attack (total and by borer species) within the tree bole from stump height to tree top, (3) damage by tree species, location and site, tree condition, and tree diameter and age.

Bark scars and distortions on the trunks of hardwoods are good indicators of wood quality. Trunk scar studies of three oak species (ms. in preparation) provide guidelines for classifying insect borer attacks, bark pockets, and overgrown branch stubs. These guidelines should be useful to timber markers and buyers in accurately appraising potential log grade and value.

Effective and efficient survey and evaluation procedures have not been developed although Morris has used "number of bark scars" for evaluation. Such procedures are badly needed by researchers for evaluating research studies and by user groups for assessing the kind and extent of damage and need for control. However, we now have the technology to develop such procedures.

Studies on the natural control of several borer species have resulted in the identification of a number of parasites (insect and nematode), predators (insect, spider, bird, animal), and diseases (fungi and bacteria). Weather also influences borer survival. Parasitism and disease incidence are low among most borer species. Predators are important, especially in combination with parasites, disease, and weather, in holding some borer populations in check, but usually these factors are not effective in knocking out infestations.

A number of silvicultural practices have been identified that offer considerable promise for reducing borer losses. Some procedures could be integrated into existing management plans with little or no additional expense by simply manipulating current practices. This area, a fruitful one for further research, needs additional study before recommendations can be developed as guidelines for user groups.

Studies of the carpenterworm sex pheromone have led to the discovery of a potent synthetic attractant. Based on a partial chemical characterization of the natural sex pheromone (w/Doolittle) together with electroantennogram studies (w/Roelofs), we began screening candidate acetates and alcohols (w/McKnight and Tagestad) and found an active material, (Z,E)-3,5-tetradecadien-1-ol acetate. Research (w/Dix) with antioxidants, isomer mixtures, bait dispensers, and trap design has increased its attractancy to being more effective than virgin females. Bases on these promising findings we established a small-scale control study utilizing the synthetic attractant to trap out the male population.

Four wooded tracts, 12-30 acres in size, surrounded by cultivated fields at least 1/4 mile wide were selected. Two replications of two trapping intensities are being used. Because the carpenterworm has a life cycle

of 1 and 2 years, the study will run for 3 years. As this year (1976) will be the third year, we should be able to evaluate trap effectiveness by late summer.

Chemical controls are needed for borers in high-value trees including selected stands managed for high-grade lumber and veneer, shade trees, ornamentals, nurseries, plantations, and seed orchards. Preliminary studies indicate trunk sprays properly timed can provide protection. Borers already established in galleries can be controlled by injecting either an insecticide or fumigant. The limited work at Stoneville, Delaware, Bottineau, Carbondale, and perhaps Wooster and other locations should be coordinated in order to obtain registration for some of the promising materials.

Summary

Current Research on Hardwood Borers

Borer Inventory

Research has provided an almost complete inventory of insect borers for the major hardwood species. For example, a recent key to the shelterbelt insects includes a number of borer pests of which the carpenterworm and ash borer have been identified as major problems on green ash, an important component of Great Plains shelterbelts. Until very recently, the pest species complex on black walnut was little studied and poorly known. Current research is filling this void. Substantial research has been done in the South. A guide to the cottonwood insect pests including six borer species was recently published and a similar guide for recognizing and identifying the major insect borers and their damage in oaks and other hardwood species in the South and Southeast is in preparation. A generally good knowledge of hardwood borers exists for hardwoods in the Northeast and one or more illustrated guides for land managers and the general public are currently being planned.

Host Damage

Damage studies are in progress on intensively cultured black walnut and cottonwood. A study relating borer populations to shelterbelt damage and effectiveness will soon be initiated in North Dakota. For further information, please refer to the Impact Summary (pg.22).

Borer Biology, Physiology, and Ecology

Current studies on borer biology and natural control and the effect of low rainfall on borer infestation levels in shelterbelts will provide companion information to an inventory key already published. Research on the insect borers of black walnut, including bud borers (*Acrobasis* spp.) and an ambrosia beetle (*Xylosandrus germanus*), is being initiated to elucidate the borers' biology and natural enemies and to identify pathogenic microorganisms transmitted by the ambrosia beetle. Although adequate biological information of the red oak borer in the oak-hickory type has been developed, current research is determining the intra- and inter-tree and stand distributions of this insect. Additionally, the sequence of attack by primary and secondary borers is under study. Comprehensive biological knowledge of the carpenterworm and several of the major cerambycid and sesiid borers of oaks and other important hardwoods has been developed in the South. A bibliography has been compiled for the carpenterworm. Results of a bark-scar study in three southern oaks will be published to provide guidelines for classifying and distinguishing insect borer attacks, bark pockets, and overgrown branch stubs.

Borer Control

Studies using carpenterworm and ash borer attractants for borer control in shelterbelts are in progress. Also, several insecticides are being tested against these pests. *Bacillus thuringiensis* and two systemic insecticides will be tested for bud borer control in black walnut plantations. Other possible control techniques to be evaluated are host resistance and silvicultural control. A silvicultural control study for the red oak borer by brood tree removal is in progress in the Northeast. The field evaluation for this study will be completed in 1977 and projections of growth and continuing infestation levels will be developed from computer analyses. Control studies of the carpenterworm using attractants and insecticides are in progress in the South and a systemic insecticide has been registered for use in cottonwood nurseries and plantations for controlling twig and stem borers.

HARDWOOD TIMBER PRODUCT TRENDS

by

Robert B. Phelps[1]

I am going to discuss with you today the present and prospective demand and supply situation for hardwood timber products. I am also going to briefly discuss the world hardwood situation with emphasis on prospective U.S. imports.

Recent Trends

United States consumption and production of hardwood timber products dropped about 13 percent in the past two- and a-half decades. In 1974, the most recent year for which we have reasonably complete data available, about 3.3 billion cubic feet (roundwood equivalent) of hardwood timber products were consumed in the U.S. (Table 1). This was some 0.5 billion below consumption 25 years ago. The major factor in the fall-off has been the declining use of round hardwoods for fuel. For example, in 1950, almost half of the hardwoods harvested were used for firewood. By 1974, consumption was less than a fourth as large and amounted to only 13 percent of total output.

In contrast to declining fuelwood use, production and consumption of hardwood industrial roundwood products (i.e., saw logs, veneer logs, pulpwood, and all other products except fuelwood) have been rising. Domestic production totaled almost 2.8 billion cubic feet in 1974, 44 percent above 1950 harvests. Consumption followed the same trends, rising to a slightly higher level because imports are somewhat larger than exports.

Although total industrial roundwood consumption and production have grown in the past two- and a-half decades, the various products have shown somewhat divergent trends in response to changing patterns of demand. Saw logs used for domestic production of hardwood lumber totaled about 1.1 billion cubic feet in 1974. This was not markedly different from output in 1950, but was above production in the late 1950's and early 1960's. Since 1962, rising consumption of railroad ties and of hardwood lumber in manufacturing, pallet production, and some other uses has about offset the declining use in construction, particularly residential construction, where consumption of hardwood flooring dropped sharply in the mid- and late-1960's.

Consumption of hardwood plywood and veneer rose steadily in the 1960's and early 1970's. However, all the increase was supplied by imports,

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TABLE 1.—*Production, imports, exports, and apparent domestic consumption of hardwood timber products, by major production, 1950–74*[1]

[Million cubic feet, roundwood equivalent]

Year	All products		Industrial roundwood used for— Total				Lumber				Plywood and veneer				Pulp products					Logs		
	Domestic production	Apparent consumption	Domestic production	Imports	Exports	Apparent consumption	Domestic production	Imports	Exports	Apparent consumption	Domestic production	Imports	Exports	Apparent consumption	Domestic production	Imports [2]	Exports [2]	Apparent consumption	Miscellaneous products [3]—apparent consumption	Imports	Exports	Fuelwood—apparent consumption
1950	3,645	3,740	1,915	125	30	2,010	1,130	45	15	1,155	160	5	(4)	165	215	55	5	260	410	20	5	1,730
1951	3,750	3,850	2,050	140	35	2,150	1,180	40	20	1,200	195	10	(4)	200	280	65	10	335	390	25	5	1,700
1952	3,470	3,540	1,935	115	40	2,010	1,105	35	25	1,115	185	10	(4)	195	270	60	10	315	370	15	5	1,530
1953	3,425	3,520	1,950	130	35	2,045	1,100	35	20	1,115	180	15	(4)	195	315	55	10	360	355	20	5	1,475
1954	3,365	3,450	1,945	130	50	2,030	1,080	30	20	1,095	165	30	(4)	190	350	55	20	380	345	15	5	1,420
1955	3,445	3,535	2,085	155	65	2,175	1,160	40	30	1,170	190	40	(4)	225	405	55	30	430	330	20	5	1,360
1956	3,485	3,595	2,185	175	60	2,295	1,220	40	30	1,230	190	45	(4)	235	455	70	25	500	310	25	5	1,300
1957	3,055	3,150	1,820	165	70	1,915	890	40	30	895	165	45	(4)	210	465	60	30	495	295	15	5	1,235
1958	2,975	3,070	1,800	155	65	1,895	920	35	25	925	155	50	(4)	205	435	55	30	460	285	15	10	1,175
1959	3,120	3,245	2,010	200	70	2,135	1,020	50	25	1,040	160	75	(4)	240	555	60	35	580	265	15	5	1,110
1960	3,040	3,125	1,995	180	90	2,080	955	45	25	975	155	60	(4)	215	615	60	55	625	255	15	10	1,045
1961	2,920	2,985	1,935	165	95	2,000	910	35	25	925	150	60	(4)	210	625	60	60	620	240	10	10	985
1962	2,970	3,075	2,055	205	100	2,160	970	45	20	1,000	150	75	(4)	220	695	70	65	700	225	10	15	915
1963	3,085	3,180	2,230	205	110	2,325	1,095	45	20	1,120	145	80	(4)	225	735	70	75	730	245	10	15	855
1964	3,145	3,240	2,350	225	125	2,445	1,110	45	20	1,135	160	90	5	245	815	75	90	800	255	10	10	795
1965	3,165	3,280	2,430	240	125	2,545	1,140	50	20	1,170	160	100	(4)	255	855	80	90	850	260	10	15	735
1966	3,200	3,340	2,525	275	140	2,665	1,180	65	25	1,220	135	110	(4)	240	945	90	100	935	255	10	15	675
1967	3,035	3,120	2,415	235	150	2,500	1,135	50	25	1,160	130	105	(4)	235	905	70	105	870	230	10	20	620
1968	2,970	3,115	2,410	310	160	2,555	1,095	55	15	1,130	135	160	5	295	940	85	125	900	220	10	20	560
1969	3,025	3,220	2,530	370	175	2,725	1,140	70	20	1,190	130	175	5	300	1,045	120	140	1,025	205	10	15	495
1970	2,905	3,030	2,470	335	205	2,595	1,090	50	20	1,120	125	165	5	280	1,050	110	170	990	195	5	15	435
1971	2,830	3,020	2,430	380	190	2,620	1,060	55	25	1,090	130	205	5	335	1,030	115	150	995	195	5	10	400
1972 [5]	2,900	3,050	2,515	450	295	2,665	1,030	70	40	1,060	145	255	5	395	1,105	115	230	990	215	5	20	385
1973 [5]	3,100	3,300	2,700	420	220	2,900	1,065	85	35	1,115	135	210	5	340	1,240	125	150	1,215	230	5	30	400
1974 [5]	3,160	3,255	2,760	335	245	2,855	1,050	70	30	1,090	115	140	10	245	1,350	120	170	1,305	210	5	35	400

[1] Columns may not add to totals because of rounding.
[2] Includes pulpwood and the pulpwood equivalent of wood pulp, paper, and board.
[3] Includes cooperage logs, poles and piling, fenceposts, hewn ties, round mine timbers, box bolts, excelsior bolts, chemical wood, shingle bolts, and miscellaneous items.
[4] Less than 2.5 million cubic feet.
[5] Preliminary estimates.
Sources: Based on data published by the U.S. Department of Commerce and Agriculture.

principally from Southeast Asia, and domestic hardwood veneer log production trended down during the period. In contrast to lumber, hardwood plywood consumption increased in new housing and other types of construction in the 60's as the use of paneling and hollow-core doors increased. Hardwood plywood consumed in shipping and a wide variety of other uses showed a particularly large increase during this period.

Until the early 1970's, production of saw logs for lumber manufacture composed the largest use for domestic hardwoods. However, production and consumption of hardwood pulpwood has been increasing rapidly since the early 1950's and currently comprises the single largest end use for domestic hardwood industrial roundwood in terms of cubic volume. In 1974, production of round hardwood pulpwood totaled almost 1.4 billion cubic feet, more than six times production in 1950.

Trends in the production and consumption of a variety of miscellaneous hardwood roundwood products (e.g., poles and piling, cooperage logs, excelsior bolts, etc.) have dropped. International trade in hardwood logs has shown divergent trends. Log imports have declined, while log exports have increased.

Prospective Trends in Demand for Hardwood Timber Products

I am sure you are all aware of the conditions in the major markets that have triggered the low levels of wood products demand in the past couple of years. Many of the declines are accentuated because they come after the phenomenal growth that took place in the early 1970's. For example, housing starts dropped sharply in 1974 and continued down in 1975. Estimated production last year was only 1.2 million single- and multi-family units and 216 thousand mobile homes. For conventional housing, this was less than half of 1972 construction and the smallest volume in nearly 30 years. For mobile homes, total shipments were only 38 percent as large as 1972 and less than in any year since 1965. In contrast to housing, other types of new construction activity showed some rise, at least in current dollar terms. However, much of the rise was apparently due to increasing costs and was for those types of construction that consume only small volumes of wood products.

Manufacturing output, including production of furniture and fixtures--major markets for hardwood lumber, plywood, and veneer--was also below 1973 and 1974 levels. As would be expected, container production--an important end use for paperboard and hardwood veneer and lumber--was also down.

We do not as yet have final data for many products, but the trends in the various markets point to a sizable drop in production and consumption for most hardwood products in 1975. Preliminary estimates indicate that hardwood industrial roundwood product output and consumption may have totaled about 2.1 billion cubic feet (roundwood equivalent) in 1975, the smallest volumes since 1962. For 1976, the outlook is somewhat brighter. Many markets have been improving and are expected to continue to do so.

Although economic conditions in many of the important hardwood timber product markets are currently at relatively low levels, and prospects are for a slow recovery in the next few months, population and prospective economic growth patterns suggest that the longer-run outlook is for a return to higher levels of demand. There has always been uncertainty about future growth trends and given current U.S. and world economic conditions, the outlook during the next few decades seems much more uncertain than it did a few years ago. However, it seems reasonable to expect that population, economic activity, and income will continue to rise in the years ahead.

Population is, of course, one of the important determinants of future market levels. Recent projections by the Bureau of the Census show that, although current fertility levels are close to those that would result in stability in the 21st century (zero population growth), population is likely to continue to increase substantially in the next 50 years. Growth in population is likely to be accompanied by rising income. Even at much lower rates of growth than has taken place in the past 50 years, per capita disposable income could be expected to increase appreciably in the next half century.

Although a large part of the additional demands generated by more people with larger incomes are expected to be for services, substantial growth in the demands for housing, furniture, and other goods, made in whole or in part from hardwood timber products, are also likely.

Trends in housing starts are of special importance in appraising prospective demands for softwood and hardwood lumber and plywood, insulation board, and particleboard. Recent projections indicate a high level of demand for housing--around 2.6 million units a year--in the early 1980's. These projections, which have been based on trends in the rate of household formation, housing replacement, and vacancies, are substantially above recent levels of housing production.

Continuing increases in the need for replacements should help sustain demand through the rest of the century and beyond. Expenditures for maintenance and repair will also rise as the housing inventory increases.

Prospective trends in population, economic activity, and disposable personal income also indicate the likelihood of some increase in the demand for factories, stores, hospitals, sewer and water systems, roads, and other related types of buildings and facilities. Growth in industrial production is expected to cause increasing demand for pallets and containers of all types.

Most paper is consumed in one form or another by individuals, with their level of use a function of income. Thus, with growth in population and disposable personal income, paper consumption is expected to increase. Pulp-based building board consumption will likely rise with construction; and growth in manufacturing and agriculture stimulates demand for paperboard and other packaging materials.

Increases in future demand for hardwood timber products will depend on many factors in addition to population and economic growth. For example, developments in technology have led to an increasing proportionate use of hardwoods, whole-tree chips, and residues in pulp manufacture. Innovations in the metals and plastics industries have resulted in the displacement of lumber and plywood in products such as furniture and containers. On the other hand, new technology has simultaneously led to large increases in the use of lumber in pallets, greater use of plywood in construction, and use of pulp and paper, plywood, hardboard, and particleboard in a wide assortment of end uses. These and other similar factors were responsible, in part, for the changes in hardwood product production and consumption in recent years pointed out earlier.

Prices and institutional changes have been and will continue to be important. However, assuming that population and economic growths increase as discussed earlier, and that price and technological trends do not change significantly in relation to competing materials, demands for most hardwood timber products are expected to rise appreciably in the next half century. For example, recent Forest Service projections developed in response to the Forest and Rangeland Renewable Resources Planning Act of 1974 (P.L. 93-378) show demand for hardwood lumber rising to 12 billion board feet by 2000 and continuing up to 14.9 billion--more than double average consumption in the past 5 years--by 2020 (Table 2). A substantial part of the projected demand is for railroad ties and for lumber for use in pallets, containers, and flooring. Lumber for these uses can be economically manufactured from relatively low quality and/or small size logs. Most of the remaining demand, however, is for lumber for use in cabinets, furniture, paneling, and other uses where quality and appearance are important. The economic manufacture of lumber for these uses requires relatively large-size and high-quality logs.

The demand for hardwood plywood is projected to rise to 10.1 billion square feet (3/8-inch basis) in 2020, also more than double consumption in the early 1970's (Table 3). Most hardwood plywood is used where quality and surface appearance are important Thus, the face ply must be manufactured from relatively large, high-quality logs.

After allowing for increases in conversion efficiences, the combined demand for hardwood saw logs and veneer logs needed to manuracture the volumes of lumber and plywood above is projected to total 14.8 billion board feet by 2000 and 18.4 billion in 2020. Some additional high-quality logs will be necessary to meet demands for other products that must be made from defect-free wood.

Implicit in the price assumption underlying these projections (constant relative prices) is the assumption that enough hardwood timber will be available from either foreign or domestic forests to satisfy demands and maintain relative price stability.

Table 2.--Hardwood lumber consumption, by major end use (medium projection, 1970 relative prices)

(Million board feet)

Year	Total	End use					
		New housing	Residential upkeep and improvements	New non-residential construction 1/	Manu-facturing	Shipping	All other uses 2/
1962	6,500	1,160	275	645	1,715	2,105	600
1970	7,300	545	135	800	2,265	2,900	655
Projections							
1980	9,390	630	140	1,060	2,890	3,910	760
1990	10,790	490	140	1,170	3,400	4,820	770
2000	11,980	465	145	1,235	3,970	5,415	750
2010	13,410	465	150	1,335	4,940	5,790	730
2020	14,870	480	160	1,390	5,510	6,630	700

1/ In addition to new construction, includes railroad ties laid as replacements in existing track.

2/ Includes upkeep and improvement of nonresidential buildings and structures; farm construction except housing; mining; made-at-home projects such as furniture, boats, and picnic tables; made-on-the-job products like advertising and display structures; and a wide variety of other miscellaneous products and uses.

Sources: Data for 1962 and 1970 based on information published by U. S. Departments of Commerce and Agriculture.

Projections: U. S. Department of Agriculture, Forest Service.

Table 3.--Hardwood plywood consumption, by major end use (medium projection, 1970 relative prices)

(Million square feet, 3/8-inch basis)

Year	Total	End use				
		New housing	Residential upkeep and improvements	New non-residential construction	Manu-facturing	All other uses 1/
1962	2,404	205	50	60	1,160	929
1970	3,747	605	150	80	861	2,051
Projections						
1980	6,125	995	200	140	1,030	3,760
1990	7,100	1,020	240	180	1,190	4,470
2000	7,910	1,100	275	225	1,560	4,750
2010	9,065	1,235	310	280	1,775	5,465
2020	10,110	1,315	355	310	2,180	5,950

1/ Includes shipping; upkeep and improvement of nonresidential buildings and structures; farm construction except housing; mining; made-at-home projects such as furniture and boats; made-on-the-job products like advertising and display structures; and a wide variety of other miscellaneous products and uses.

Note: Veneer is included in the estimates for manufacturing and shipping.

Sources: Data for 1962 and 1970 based on data published by the U. S. Departments of Commerce and Agriculture.

Projections: U. S. Department of Agriculture, Forest Service.

Potential Trade in Hardwood Timber Products

Although a large part of the hardwood forest resources of the world has never been adequately surveyed, available data show they are extensive. Recent estimates indicate that world hardwood forests cover some 6 billion acres and contain about 8.2 trillion cubic feet of timber (Table 4). Most of the hardwood resource is located in the tropical regions of Africa, South and Central America, and Southeast Asia. United States hardwood timber product imports, mainly from these areas, have been rising rapidly. For example, in 1972, the roundwood equivalent of hardwood timber products imports was some 3.6 times larger than imports in 1950 (Table 1).

With regard to the future, it is likely that hardwood forests in many regions of the world can support higher levels of harvest in the next several decades. Most of this potential is in the forests of Latin America, Southeast Asia, and Africa. The tropical hardwood forests are extensive and have a large capacity for timber growing, but there are serious constraints on the capability of these forests to continue to supply high-quality timber products to world markets. For example, much of the tropical forest area is relatively inaccessible, and development of timber resources is slow and expensive. Utilization of timber is also complicated by the great numbers of species of widely different characteristics. Such problems of heterogeneity are less severe in Africa and least in Southeast Asia, but occur in all regions. The future of tropical forests in all regions is also further complicated by the expanding need for agricultural land to accommodate rapidly growing populations.

In addition to the physical and other factors cited above, continued growth in demand by the major European countries and Japan will put increasing pressure on the tropical hardwood resource. The available data on prospective growth in demand for hardwood timber products in the major consuming countries and regions of the world also suggests continuing growth in markets for U.S. products. Accordingly, exports are expected to rise.

In spite of growing world demands for hardwood products and the problems associated with exploiting the hardwood resource, it seems likely that the U.S. imports from the tropical forests will show some further increase.

Increases in imports can meet part of the projected growth in demand for hardwood timber products. Improvements in utilization can also help. However, these potentials are relatively small in comparison to the total growth in demand. Thus, the Nation must look to its domestic timber resources as the best means of attaining some stability in relative prices of timber products.

Trends in Domestic Timber Supplies

In 1970, the latest year for which data are available, there were about 267 million acres of commercial hardwood forest types in the United States.

Table 4.--Forest growing stock in the world, by area and species group

(Billion cubic feet)

Area	Total	Soft-woods	Hard-woods
North America	2,083	1,395	689
Latin America	4,340	99	4,241
Europe	473	290	184
Africa	1,232	11	1,222
Asia (except Japan and U.S.S.R.)	1,444	212	1,232
Japan	67	35	32
U.S.S.R.	2,807	2,345	463
Pacific Area	177	11	166
World	12,623	4,396	8,227

Source: Food and Agriculture Organization of the United Nations. Supply of wood materials for housing. World Consultation on the Use of Wood Housing, Secretariat Pap., Sect. 2. 1971.

The oak-hickory, maple-beech-birch, and bottom-land hardwoods comprise most of this area. All but 5 percent of these hardwoods are in the Eastern United States.

As of January 1, 1971, the total volume of hardwood growing stock in all forest types was 217 billion cubic feet, or about a third of total inventories of all species (Table 5). Included in these volumes is about 515 billion board feet of sawtimber.

A third of the eastern hardwood sawtimber volume was in "so-called" select species--select white and red oaks, hard maple, yellow birch, sweet gum, yellow-poplar, ash, black walnut, and black cherry--that are preferred for cabinet work, paneling, furniture, and other uses where quality and/or surface appearance are important considerations (Table 6). The rest of the hardwood sawtimber--some 320 billion board feet in total--was composed of other species such as upland oaks, hickory, beech, cottonwood, and various other species that have more limited potential as a source of high-quality hardwood products.

Only a fifth of the eastern hardwood sawtimber inventory was in trees 19 inches or larger in diameter at breast height (Table 7). Nearly half was between 11 and 15 inches. Thus, a limited part of the hardwood sawtimber resource is suitable for high-grade saw logs or veneer logs. Producers of hardwood veneer, plywood, and high-grade lumber for furniture, for example, face more serious supply problems than the producers of pallets, construction lumber, and railroad ties.

In response to fire protection and other forestry programs, hardwood timber inventories have been increasing. Between 1952 and 1970, the inventory of hardwood sawtimber in the United States increased about 19 percent (Table 8). Although there were increases in the volumes of all sawtimber classes during this period, nearly two-thirds of the total increase was concentrated in trees 11 to 15 inches in diameter.

Most growth in inventory has also been in species such as the upland oaks, hickory, beech, cottonwood, and soft maple. There were increases in the inventory of some preferred species such as the select white and red oaks, hard maple, and yellow-poplar. But the inventory in yellow birch, sweetgum, and black walnut declined.

Most of the important hardwood regions showed some expansion in hardwood sawtimber inventories in the 1952-1970 period. The largest gains were in the Middle Atlantic, Lake States, and Central regions. The West Gulf and East Gulf regions were the only ones showing a decline. The drop was largest in the West Gulf region and for bottom-land species as a result of both logging and land clearing.

The trends in inventory provide one measure of the changing hardwood timber situation in the U.S. Another important measure is the relationship between net annual growth and annual removals. In 1970, the net

Table 5.--Growing stock and sawtimber inventories on commercial timberlands in the United States, by section and softwoods and hardwoods, 1970

GROWING STOCK

Section	All species		Softwoods		Hardwoods	
	Volume	Proportion	Volume	Proportion	Volume	Proportion
	Billion cu.ft.	Percent	Billion cu.ft.	Percent	Billion cu.ft.	Percent
North	155.7	24.0	39.1	9.0	116.6	53.7
South	159.5	24.6	78.4	18.2	81.1	37.4
Rocky Mountains	92.2	14.2	87.7	20.3	4.5	2.1
Pacific Coast	241.5	37.2	226.6	52.5	14.8	6.8
Total	648.9	100.0	431.9	100.0	217.0	100.0

SAWTIMBER

Section	All species Volume	All species Proportion	Softwoods Volume	Softwoods Proportion	Hardwoods Volume	Hardwoods Proportion
	Billion bd.ft.	Percent	Billion bd.ft.	Percent	Billion bd.ft.	Percent
North	331.9	13.7	80.1	4.2	251.8	48.8
South	483.9	20.0	275.9	14.5	208.0	40.4
Rocky Mountains	364.4	15.1	355.1	18.6	9.3	1.8
Pacific Coast	1,240.6	51.2	1,194.2	62.7	46.4	9.0
Total	2,420.8	100.0	1,905.3	100.0	515.5	100.0

Note: Columns may not add to totals because of rounding.

Source: U. S. Department of Agriculture, Forest Service. The outlook for timber in the United States. Forest Resource Rep. 20. 367 p. 1973.

Table 6.--Net volume of hardwood sawtimber on commercial forest land in the United States, by section, region, and species, 1970

(Million board feet, International 1/4-inch log rule)

Species	Total	North					South					West
		Total	New England	Middle Atlantic	Lake States	Central	Total	South Atlantic	East Gulf	Central Gulf	West Gulf	
Eastern species												
Select white oaks	46,300	25,978	548	7,773	3,121	14,535	20,322	8,635	1,428	6,412	3,846	--
Select red oaks	39,534	28,276	2,552	12,538	6,449	6,736	11,257	4,445	895	3,353	2,563	--
Other white oaks	32,388	13,378	67	7,290	--	6,021	19,010	6,147	2,470	4,922	5,470	--
Other red oaks	66,680	27,242	500	9,363	1,926	15,451	39,438	11,871	6,115	11,048	10,403	--
Hickory	30,914	12,819	152	4,428	401	7,836	18,095	4,951	1,809	6,370	4,963	--
Yellow birch	7,323	7,186	3,192	1,595	2,391	7	136	108	1	27	--	--
Hard maple	25,757	24,724	5,489	7,253	9,271	2,709	1,033	446	47	488	51	--
Soft maple	23,869	17,471	3,272	6,793	3,989	3,416	6,398	3,669	1,494	884	349	--
Beech	15,648	12,640	2,185	5,577	1,844	3,033	3,007	1,190	162	1,056	598	--
Sweetgum	26,318	1,971	--	841	--	1,129	24,346	8,263	3,451	5,338	7,293	--
Tupelo & blackgum	25,505	2,007	--	1,210	--	797	23,497	9,014	6,048	4,178	4,256	--
Ash	15,957	9,655	955	2,765	2,834	3,100	6,301	1,453	1,203	1,633	2,011	--
Cottonwood & aspen	16,771	15,043	829	829	9,934	3,451	1,727	188	25	810	702	--
Basswood	8,502	7,653	340	2,481	3,683	1,148	849	451	69	267	60	--
Yellow poplar	25,093	11,288	127	6,720	32	4,408	13,804	8,032	1,663	4,065	43	--
Black walnut	2,544	2,061	--	428	35	1,597	483	217	16	182	66	--
Other hwds.	50,672	32,406	2,244	9,958	9,346	10,856	18,265	3,824	2,489	5,147	6,803	--
Western species												
Cottonwood & aspen	12,077	--	--	--	--	--	--	--	--	--	--	12,077
Red alder	24,842	--	--	--	--	--	--	--	--	--	--	24,842
Oak	3,064	--	--	--	--	--	--	--	--	--	--	3,064
Other hwds.	15,713	--	--	--	--	--	--	--	--	--	--	15,713
Total all species	515,477	251,806	22,456	87,848	55,263	86,237	207,974	72,910	29,392	56,188	49,483	55,696

Note: Data may not add to totals because of rounding.

Source: See source note, Table 5.

Table 7.--Net volume of hardwood sawtimber on commerical forest land in the United States, by species and diameter class, 1970

(Million board feet international 1/4 inch log rule)

Diameter class	Total all hardwood species	Eastern Hardwoods										Western hardwoods
		Total	Select White & red oaks	Other white & red oaks	Hickory	Yellow birch	Hard maple	Sweet gum	Ash walnut & black Cherry	Yellow Poplar	Other hardwoods	
11.0 to 13.0	122,882	112,283	19,664	21,727	7,985	1,664	6,164	6,471	7,452	5,251	35,897	10,599
13.0 to 15.0	112,934	103,171	19,360	21,218	7,095	1,610	5,760	6,524	6,027	5,750	29,818	9,763
Total 11.0 to 15.0	235,816	215,454	39,024	42,945	15,080	3,274	11,924	12,995	13,479	11,001	65,715	20,362
15.0 to 17.0	88,904	80,924	14,947	17,341	5,589	1,259	4,459	4,862	4,609	4,933	22,918	7,980
17.0 to 19.0	63,961	57,309	10,580	12,831	3,691	915	3,453	3,397	2,965	3,557	15,913	6,652
Total 15.0 to 19.0	152,865	138,233	25,527	30,172	9,280	2,174	7,912	8,259	7,574	8,490	38,831	14,632
19.0 to 29.0	100,376	95,327	18,803	22,761	6,023	1,713	5,563	4,724	4,080	5,189	26,456	5,049
29 + ...	26,414	10,764	2,475	3,183	529	159	357	336	263	410	3,046	15,650
Total 19 + ...	126,790	106,091	21,278	25,944	6,552	1,872	5,920	5,060	4,343	5,599	29,502	20,699
All diameter	515,477	459,781	85,834	99,068	30,914	7,323	25,757	26,318	25,404	25,093	134,064	55,696

Note: Data may not add to totals because of rounding.

Source: See source note, Table 5.

Table 8.--Net volume of hardwood sawtimber on commercial forest land in the U.S. by section, region, and State, as of December 31, 1952 and 1962, and January 1, 1970

[Million board feet, International 1/4-inch log rule]

Section, region and State	All ownerships		
	1952	1962	1970
New England:			
Connecticut	1,596	2,106	2,265
Maine	9,807	10,556	11,063
Massachusetts	1,360	1,660	1,803
New Hampshire	3,075	2,995	3,178
Rhode Island	136	146	167
Vermont	4,626	4,124	3,977
Total	20,600	21,587	22,456
Middle Atlantic:			
Delaware	573	734	900
Maryland	5,042	5,291	5,680
New Jersey	2,325	2,975	3,527
New York	16,096	16,971	17,706
Pennsylvania	16,670	21,908	26,182
West Virginia	22,716	28,538	33,850
Total	63,422	76,417	87,848
Lake States:			
Michigan	16,764	22,339	27,061
Minnesota	6,354	8,958	12,025
North Dakota	509	524	563
South Dakota	204	228	280
Wisconsin	10,260	13,582	15,332
Total	34,091	45,631	55,263
Central:			
Illinois	9,488	8,548	7,809
Indiana	8,754	10,258	11,025
Iowa	5,053	5,709	6,586
Kansas	1,706	1,760	1,902
Kentucky	21,311	24,382	28,231
Missouri	10,828	12,600	14,977
Nebraska	1,070	1,441	1,502
Ohio	11,039	13,148	14,201
Total	69,251	77,848	86,237
Total North:	187,364	221,484	251,806
South Atlantic:			
North Carolina	26,327	27,998	29,516
South Carolina	14,259	14,305	16,051
Virginia	22,827	25,480	27,342
Total	63,413	67,783	72,910
East Gulf:			
Florida	9,207	9,541	10,498
Georgia	20,259	19,519	18,893
Total	29,466	29,060	29,392
Central Gulf:			
Alabama	18,194	18,295	17,894
Mississippi	16,854	16,081	16,652
Tenessee	18,128	19,431	21,641
Total	53,176	53,807	56,188
West Gulf:			
Arkansas	25,031	22,828	21,134
Louisiana	22,397	20,594	18,985
Oklahoma	1,988	1,844	1,701
Texas	10,025	8,614	7,662
Total	59,441	53,880	49,483
Total South:	205,496	204,530	207,974
Pacific Northwest:			
Alaska-Coastal	1,268	1,279	1,273
-Interior	0	0	0
-Summary	1,268	1,279	1,273
Oregon-Western	15,733	19,564	22,975
-Eastern	68	80	89
-Summary	15,801	19,644	23,064
Washington-Western	7,585	11,473	14,898
-Eastern	356	366	423
-Summary	7,941	11,839	15,321
Total	25,010	32,762	30,658
Pacific Southwest:			
California	5,575	5,725	5,901
Hawaii	722	722	834
Total	6,297	6,447	6,735
Total Pacific:	31,307	39,209	46,394
Northern Rocky Mountains:			
Idaho	700	698	679
Montana	1,006	1,070	1,092
S. Dakota (West)	6	7	9
Wyoming	291	320	324
Total	2,003	2,095	2,105
Southern Rocky Mountains:			
Arizona	572	646	678
Colorado	3,517	3,832	3,442
Nevada	24	27	24
New Mexico	1,372	1,505	1,574
Utah	1,416	1,475	1,476
Total	6,901	7,485	7,196
Total Rocky Mountains:	8,904	9,580	9,301
Total all regions:	433,072	474,804	515,477

Source: See source note, Table 5.

annual growth of growing stock was 7.9 billion cubic feet--some 79 percent above the removals of 4.4 billion. For sawtimber size trees, the excess of growth over removals was somewhat less-about 31 percent (Table 9).

For those species for which separate data are available, the net annual growth of sawtimber was in excess of removals for all except sweetgum and yellow birch. For some of the other species, such as the oaks, yellow-poplar, and those included in other eastern hardwoods, the excess of growth over removals is substantial.

Although the data on trends in inventory, growth, and removals indicate that the hardwood timber situation in the United States has been improving for most species and in most major hardwood-producing regions, the aggregate figures conceal some problems. For example, the hardwood sawtimber volumes are dispersed over not only the 267 million acres in the hardwood types but also as scattered trees in the softwood types. Much of the larger size timber suitable for the manufacture of high-quality lumber and veneer occurs as single trees or groups of trees that are not economically harvestable. In addition, part of the hardwood timber in the East is in small private tracts used primarily for homesites, recreation, or other nontimber purposes not compatible with timber harvesting.

Despite these limitations, it is clear that the hardwood forests can support an increased level of cutting. Although a substantial part of the available timber is so small or of such poor quality that it is best suited for pulp manufacture, the cut of sawtimber-size material could be increased by possibly 2 to 3 billion board feet annually.

Projections, based on the assumption that 1970 levels of management will continue, indicate that the supply of hardwood sawtimber will materially increase over the next couple decades. The projections of demand outlined earlier are somewhat below projected supplies for the next decade or so. This suggests that most of the rise in demand, at least during the next few years, can be met from prospective supplies.

Beyond the next few years, the outlook is not so promising because projected demands under above conditions rise more rapidly than projected supplies. The prospective shortfall could be accentuated by additional losses in the area available for hardwood timber production such as the decline in bottom-land hardwood forests in the South mentioned before. Further conversion of this kind, the expansion of cities, and withdrawals for highways, reservoirs, parks, and other uses could substantially reduce supplies of hardwood sawtimber below the projected levels. In addition, comparisons of prospective <u>softwood</u> timber demands and supplies point to rising prices for those species, with probable acceleration of conversion of hardwood lands to pine plantations.

Thus, the longer run, demand-supply situation indicates that the country is faced with increasing competition for the available hardwood timber

Table 9.--Net annual growth and removals of hardwood sawtimber on commercial forest land in the United States, by species, section, and region, 1970

(Thousand board feet, International 1/4-inch rule)

Section and region	Total		Select white and red oaks		Other white and red oaks		Hickory		Yellow birch	
	Growth	Removals	Growth	Removals	Growth	Removals	Growth	Removals	Growth	Removals
New England	679,653	773,162	109,988	121,888	16,079	9,517	4,300	1,523	59,325	149,906
Middle Atlantic	3,309,294	1,858,078	788,919	456,280	535,060	323,754	115,371	72,190	29,695	16,460
Lake States	2,744,840	1,581,506	419,407	257,697	93,869	44,854	19,202	3,736	53,419	56,645
Central	3,342,060	2,675,547	776,149	794,152	782,038	588,422	271,305	107,375	338	--
Total, North	10,075,847	6,848,293	2,094,463	1,630,017	1,427,046	966,547	410,178	184,824	142,777	223,011
South Atlantic	2,658,204	2,033,757	484,805	361,996	671,838	420,303	137,668	75,281	4,989	380
East Gulf	1,207,378	908,118	96,599	60,739	340,858	221,729	49,980	34,278	--	708
Central Gulf	2,526,416	2,499,207	433,588	311,811	768,211	642,099	287,660	239,157	700	500
West Gulf	1,540,320	2,353,449	226,308	341,899	525,135	862,185	153,632	192,238	--	--
Total, South	7,932,318	7,794,531	1,241,300	1,076,445	2,306,042	2,146,316	628,940	540,954	5,689	1,588
Total, West	1,654,221	388,484	--	--	--	--	--	--	--	--
Total, All Regions	19,662,386	15,031,308	3,335,763	2,706,462	3,733,088	3,112,863	1,039,118	725,778	148,466	224,599

Section and region	Hard maple		Sweetgum		Ash, walnut and black cherry		Yellow-poplar		Other hardwoods	
	Growth	Removals	Growth	Removals	Growth	Removals	Growth	Removals	Growth	Removals
New England	112,846	135,340	--	--	35,266	49,068	4,176	1,333	337,673	264,587
Middle Atlantic	286,674	195,449	30,917	6,064	326,941	121,502	287,088	208,457	908,629	457,922
Lake States	352,556	213,024	--	--	130,275	48,591	888	--	1,675,224	956,959
Central	98,163	92,787	50,589	29,222	248,647	196,415	272,195	151,983	842,636	715,191
Total, North	850,239	636,600	81,506	35,286	741,129	415,576	564,347	361,773	3,764,162	2,394,659
South Atlantic	11,109	7,633	314,888	300,503	63,490	50,339	441,904	281,714	527,513	535,608
East Gulf	1,489	2,067	172,226	189,565	43,110	22,611	106,474	102,447	396,642	273,974
Central Gulf	24,393	15,572	202,211	449,614	105,529	83,801	180,438	161,791	523,686	594,862
West Gulf	2,191	746	219,899	284,901	58,817	83,695	1,035	1,298	353,303	586,487
Total, South	39,182	26,018	909,224	1,224,583	270,946	240,446	729,851	547,250	1,801,144	1,990,931
Total, West	--	--	--	--	--	--	--	--	1,654,221	388,484
Total, All Regions	889,421	662,618	990,730	1,259,869	1,012,075	656,022	1,294,198	909,023	7,219,527	4,774,074

Note: Data may not add to totals because of rounding.

Source: See source note, Table 5.

and rising prices. The problem is likely to be particularly severe for the industries producing relatively high-quality lumber and plywood from preferred species. Nevertheless, all industries, including the railroad tie, pallet, and pulp and paper industries, will be affected directly or indirectly by increasing competition for the available timber supplies; as all industries draw, to some extent, on the same timber, and price increases for some types will affect other species and sizes.

The longer run outlook is based on the assumption that recent trends in management will continue. The hardwood forest lands in the United States have the capability, under intensive management, of producing enough hardwood timber to meet projected demands at prices close to recent levels for several decades.

Intensified management would involve increases in investments in such measures as planting, thinning, and other stand improvement methods. More effective protection against destructive agents such as insects and disease would also increase the quantity and quality of the resource. There is a related need for acceleration of research programs designed to devise improved management, protection, and utilization methods.

HARDWOOD BORER RESEARCH NEEDS FOR COOPERATIVE FORESTRY IMPLEMENTATION

by

Eldon M. Estep[1/]

Research implementation activities of Cooperative Forestry are aimed primarily at the forest management needs of private, nonindustrial landowners, and the forest products utilization needs of loggers and wood processors. Hardwood borer research needs of these audiences are not unique--they are basically the same as those of all public and private landowners. These needs, however, are of paramount importance in any program seeking to increase hardwoods' share of the country's annual wood consumption, and in programs mounted to help the Nation capture a fuller share of the potential represented by privately held forest resources.

Generally, the technology transfer specialists need tools and techniques that will help users recognize and mitigate the impacts of present and past borer activities, plus controls that will prevent or minimize losses from future hardwood borer attacks. Considerable work has already been done to identify the borer-host species combinations that represent the most serious losses. Undoubtedly, more needs to be done to insure that limited resources for research and control are applied to the most pressing needs to insure maximum benefits.

Control measures for high priority borer-host combinations are an obvious research need. This implies the research needed to develop knowledge about an insect on which to base control measures. It also implies controls that are economically feasible for stands, individual trees, and in some cases, freshly cut logs. Measures to prevent both reattacks and new attacks are required. Controls by chemical application or simply timely application of basic silvicultural practices are needed.

Recognition of the influence poor site and low vigor can play in attacks by some borers can guide initial stand establishment efforts, including species selection, and can emphasize the benefits of timber stand improvement. Tools to determine the need for control activities are required for use as appropriate on timber stands or individual trees. Sampling procedures for insect activity surveys and guides to tree form characteristics and other surface indications of borer activity can lead to controls being applied at the most opportune time--from a spray program to removal of brood trees.

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Frass keys and other tools for borer identification, as well as better log and tree indicators of borer damage, can greatly aid in timber evaluation. Aids to appraisal of standing timber and payment of log prices realistically related to the volume and value of recovered products will contribute to a healthy marketplace operation.

The uncertainties caused by borers in growing, buying, and selling hardwoods must be overcome. Our success in meeting research needs in hardwood forest management and utilization will be directly related to how well we are able to answer these hardwood borer research needs.

REDUCING THE IMPACT OF OAK BORERS
BY SILVICULTURAL METHODS

by

Ivan L. Sander and Robert E. Phares[1/]

Any successful silvicultural system must take into consideration the importance of creating stands with adequate resistance and tolerance to insects, diseases, and other injurious factors. Sometimes our management practices may be almost entirely governed by these considerations. Examples of minimizing damage by modification of silvicultural systems are many and varied due to the wide range of damaging agencies that our forest resources are subjected to. The silvicultural approach to reducing losses to damaging agencies is mainly one of avoiding the conditions, environmental or otherwise, that are conducive to damage. The direct measures, including such steps as salvage of damaged trees and use of pesticides, are often used only when silvicultural systems have proven ineffective, or, as is often the case, were not applied. Graham (1959) has noted that the indirect silvicultural methods of control are often the slowest to take effect but the most enduring.

In order to fully assess the opportunities for control of oak borer damage by silvicultural measures, it is first necessary to define the framework within which our silvicultural prescriptions and silvicultural practices are developed to meet specified management objectives. We will limit our discussion to the single objective of wood production although it must be recognized that forest management objectives often include many other goals.

Current Silvicultural Practices

The basic objective of silvicultural practices in the eastern hardwood region is to grow full yields of the highest value products the site can produce in the shortest time possible. Our product objective is high-quality sawtimber and veneer trees although pulpwood and other small products may be harvested during the interim. Thus, we are primarily interested in large diameter trees with the maximum amount of clear wood in the outer portion of the bole.

With the exception of the northern hardwoods, most of the eastern hardwoods are managed under even-aged management systems. Most of our commercially important hardwoods in the oak-hickory and eastern mixed hardwood forest types are intolerant to only moderately tolerant and therefore do not reproduce well under the heavy shade conditions characteristic of the uneven-aged selection systems. Heavy emphasis on even-aged management systems will likely continue although there may be increasing use of group selection cutting systems in the future if some of the pending legislative actions now being considered are passed.

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With even-aged harvesting systems, there are only a few times in the rotation when entry is made into individual stands. The first entry usually occurs after the reproduction period when crown closure is essentially complete, potential crop trees can be easily identified, and growth is beginning to slow down as a result of the increasing stand density. This usually occurs 10 to 15 years after the previous stand has been harvested and the area is regenerated. A cleaning is usually recommended at this stage in the rotation to release potential crop trees from trees of less desirable species or form. Cleanings, however, are expensive and are usually done only on the better sites. For the majority of our hardwood stands on average sites, cultural practices are often delayed until a light commercial thinning can be made--usually at 25 to 30 years of age.

Very few hardwood stands receive more than two intermediate cuttings prior to final harvest. Unless these cuts are fairly heavy they often are uneconomical because of the low value of material being removed, and the high costs related to sale administration, marking, and logging road renovation. Frequent light cuttings, therefore, are quite impractical. For oaks, the stop-thinning age is about three-fourths of the rotation age or about 60 years on medium sites and less on better sites. Thus, current management of our eastern hardwood stands is characterized by limited opportunities to carry out sanitation practices throughout the rotation.

Research Needs

Now let's talk about research needs from a silviculturist's viewpoint. First of all, control of borers must be preventive. If a borer attack is successful, the damage is done and tree quality is lowered. The potential effectiveness of preventive control through silvicultural practices is directly proportional to the intensity of those practices. And, the intensity of silviculture we can practice is to a large extent dictated by the cost of the practice in relation to the benefits accrued and the value of the products we are growing.

Control measures that depend on chemical insecticides are likely to be too expensive to get silviculturists very excited. Furthermore, timing of chemical application may be critical. For example, if the application must coincide with adult emergence, or an egg hatch, the logistics are likely to be impossible.

The use of sex attractants may have possibilities, but here again timing could be critical and at our present level of practice, silviculturists simply do not have the resources to effectively use such control measures.

Of course, in the few instances where we intensively culture species that are very valuable, such as black walnut, the use of insecticides or attractant substances becomes more feasible and probably economically justifiable.

Biological control through the use of parasites and/or predators might be a viable alternative for silviculturists. This may be especially true if a parasite population can be established and is then able to maintain itself. But, if the parasite has to be reintroduced annually or at frequent intervals, this kind of control is likely to have little appeal to silviculturists.

If borers can be controlled through the application of ordinary, day-to-day silvicultural operations, the control can be readily accomplished and will likely be much more permanent than the temporary reduction in borers that can be attained by using chemicals. At the present time, however, we have no good information on which to base silvicultural control. To our knowledge, the only information available is based on some work John Hay did in Kentucky a number of years ago with the red oak borer. Thus, his recommendations, even though good, are of limited use. Red oak borers emerge every other year, and their numbers can be reduced by removing susceptible trees early in the growing season of the year in which they emerge. Unfortunately, silviculturists cannot restrict their thinning operations or any operations only 1 year out of 2. They have to maintain continuity in their operations from year-to-year and throughout each year.

From a silvicultural viewpoint, the identification of the characteristics a tree possesses that make it susceptible to successful attack is most important and of highest research priority. Unless we can readily identify high-risk trees, silvicultural control of borers will not be effective. In developing a profile of high-risk trees, we must ask the following questions. What is its crown class? Is age or tree size a factor? How about species, bark thickness, and texture? Is vigor, expressed as growth rate, or as some other index, important? How about site quality? Should all highly susceptible trees be removed from a stand, or will this increase the probability of attack on the remaining trees? Do trees, once attacked, have any ability to reject that attack before the larvae penetrate to the wood, or can this ability be induced through some cultural treatment such as fertilization? As previously noted, most hardwoods in the Eastern United States are being managed under an even-aged system. This means the entire stand is removed at the end of a rotation. When this stand is removed, does the incidence of borer attack in the surrounding stands increase, and if so, is there anything that can be done about it?

Research should be conducted in regulated or thinned stands. As time passes, more and more stands will be regulated, thinned, or managed, and if research results are to be useful, they must apply to such stands. In the case of upland central hardwoods, oak-hickory, or Appalachian hardwoods, we think research should be restricted to stands 60 years old or less. By the time a stand is 60 years old, the die is cast. Thinnings are relatively ineffective if started this late although they are of some benefit. Younger stands have a much higher priority and a much better potential for developing quality trees.

Remember that a major objective of hardwood silviculture is to develop quality. Although a tree cannot yield a Number 1 sawlog until it is about 18 inches d.b.h., it cannot yield a Number 1 sawlog even then unless the development of defect-free wood started long before the tree attained that size.

Borer galleries confined to the central core of about 6 inches are of little or no consequence. This core generally contains many knots and is inherently low quality wood. Beyond this core, however, borer galleries are not welcome.

The trees within a timber stand are potentially useful for a variety of products. Quality as measured by defects in the wood is generally not limiting for products such as pulpwood or charcoal wood and trees producing these products are generally the first trees removed in thinnings after age 20. The trees we really want to develop into high quality defect-free trees are those we retain until the end of the rotation. If we could reach this point with a majority of trees containing a veneer log plus maybe a Number 1 or 2 sawlog, we would have it made. We can't do this though without some practical way to control, or at least reduce, damage from borers.

The intensive culture of individual species, especially those with high values such as black walnut, is becoming increasingly feasible. Silvicultural practices other than thinning associated with intensive culture such as fertilization, pruning, and cultivation may have some influence on susceptibility to borer attack. Size and severity of pruning wounds, dead branch stubs, and rate of healing could be important. Where intensive culture is practiced, using chemical and silvicultural control becomes more feasible because the product we are attempting to produce, veneer or top quality sawlogs, have such a high value.

Summary

We think much can be accomplished in controlling or reducing borer attack through silvicultural operations. However, silviculturists must know what to look for and must have solid information upon which to base control decisions. And the techniques must be preventive; there is little use in closing the barn door after the horse has escaped.

If all else fails, perhaps we should engage some bright, creative, merchandising types to coin catchy names for wood products with borer galleries in them. After all, if rocks can be sold as pets, there ought to be a place for rufulued oak, or sculptured poplar, or holey oak, or something.

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HARDWOOD BORER RESEARCH NEEDS OF A STATE AND PRIVATE USER

by

Kenneth H. Knauer[1/]

Six years ago, I was hired by the Southeastern Area as a hardwood insect specialist. My first job was to undertake a problem analysis to identify opportunities and responsibilities for State and Private, Forest Insect and Disease Management, in hardwood insect work. I concluded that, of the three hardwood damage groups, defoliators, borers, and regeneration insects, no one worried about defoliators until an outbreak occurred. The easy remedy, of course, was to spray them with something. Forest managers were not willing or able to take whatever steps might be available--and there are very few available--to avoid a defoliator outbreak. Consequently, I dismissed defoliators as a group against which State and Private should direct their attention. Hardwood borers represented the next most significant damage group. I gave hardwood borers a low priority for the same reasons I mentioned for defoliators. Forest management has not progressed to the point where, either because of finances or technology, wood borer attacks can be prevented in the forest. Yesterday, the industry representatives asked for help in utilizing the borer-infested material more efficiently. They also talked about increasing their profit margins. The concern is still damage, not prevention; insect and disease programs have little opportunity to influence losses to hardwood borers while hardwood management remains relatively passive.

The third damage group I identified was what I called the "hardwood regeneration insect complex." When we heard some mention of that group yesterday, I was a little gratified. Given 2,000 to 10,000 stems per acre following a hardwood clear-cut, we have no idea what influence insects have on the survival, growth rate, form or composition of the next stand of trees. We don't even know the identity of the insects in the complex. My conclusions were that if FIDM were going to do anything, the regeneration insect complex was the group with which we should be working. Since there was no strong support from State Foresters and forest industry representatives, and since hardwood management was still at a relatively low intensity, I suggested that financing a hardwood entomology staff position in the Southeastern Area might be premature.

The objective of this meeting is to bring together those people interested in doing something about hardwood borer damage. Previous speakers have already suggested that we must begin to reexamine our programs to see if we can't come up with some new directions. Particularly important is the need to think about multifunctional solutions to forest management problems, downplaying our natural instincts to view everything as an insect management problem. If we do nothing about the current functional alignment of our research and pest management projects, and if Research and

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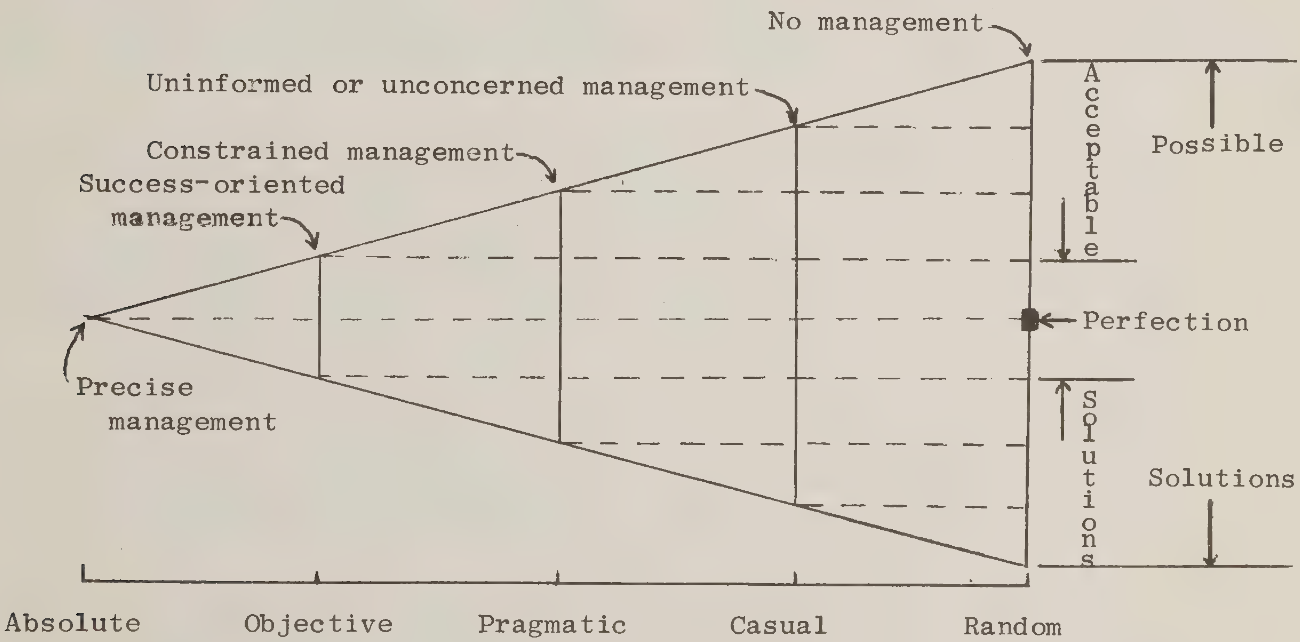
State and Private Forestry cannot forge a productive partnership, then we will fail to accomplish our common objective and this will be a pretty expensive gathering to relearn an old lesson.

I'm going to address my comments to the administrators who establish program direction. What we must discuss are management policies and administrative decisionmaking. The corners we find ourselves in, our urgent need for answers, our inability to be responsive to industry, are all directly related to management. How can we justify having a researcher work for 15 years in fine tuning a system for which there is no user? How can we spend millions of dollars for control when there are no markets?

I'll use this illustration to demonstrate my impression of our forest management administration dilemma.



GOAL ATTAINMENT STANDARDS

The vertical lines within the cone represent the precision or accuracy (probability of being right, if you will) required or accepted by the respective management patterns. My impression, and the source of my frustration, is that research can accept only a perfect solution; in fact, research targets a perfect solution, frequently unmindful of the costs either to themselves or to potential users. All too frequently, however, by failing to establish realistic goals, a research project will be unsuccessful in goal accomplishment.

Our problem, as I see it, is that hardwood forest management lies somewhere between the pragmatic and the casual levels of management. The people to whom our research should really be directed are the managers between the objective and pragmatic levels. Even economically constrained program managers are willing to tighten their belts if we can help them identify the alternatives available to them, can provide them with the cost efficiency for each alternative, and can give some indication of the probability of success. I honestly feel that if research can move toward the more flexible success oriented objective management level, both the researchers and the users will be more satisfied with the results.

Six years ago when I made my hardwood insect problem analysis, managers of hardwood forests had little awareness of the actual or potential insect problems confronting them. The situation is not much changed today. These managers have either conditioned themselves to ignore insect-related inconvenience or have made administrative or technical adjustments that make the inconvenience tolerable. In essence, they learned to live with the problem. That is pragmatic management. How justified are we, therefore, in concentrating our efforts toward finding the ideal solution--the panacea?

So we massage our scientific integrity and say, "o.k., we'll set our sights to try and answer questions about the broad picture, recognizing that forest managers may not be quite sophisticated enough to fully employ the answers obtained." We have a couple of things to resolve first, however. It is not a matter of whether we want to work on insect life histories, life tables, pesticides, or simulation models. It's whether we want to work together. The only way we are going to get together is to abandon the functional tunnel vision that dominates our programs and our policies. There are some areas that management must zero in on. I tried my best yesterday to get Tom Hofacker to say that registering pheromones is expensive. He wouldn't say it, but registering pheromones for insect control is expensive. Can Research really afford the proliferation of pheromone work that we learned about yesterday?

I've been to meetings before where we were asked how FI&DM could participate and become a more active partner in research and development. FI&DM's needs and S&PF's needs are no different than the needs of forest industry or the needs of the State Foresters. We find it very difficult, however, particularly with insect and disease research, to identify efforts in which we can invest dollars or people. Even when we can identify areas such as silvicultural manipulation and life history and life cycle work, and then suggest pilot evaluations of the systems proposed, we are told, "well, we're not really ready to put it on the line. We're not really ready to give it a robust test." When? How will you know when you're ready? Who is it that makes the decision in our organizations to take chances? The National Forests, in addition to growing timber, can be used as demonstration areas, as laboratories. We are not using them. The point was made yesterday that we should "Work in the managed stands." Well, who has the managed stands? Identify those stands. Incorporate your efforts into those of the silviculturists, the economists,

and the forest managers. We must begin to get insect and disease programs into a supportive role where I feel we belong and have the greatest opportunity for significant accomplishments.

Insect and Disease Research should not be expected to solve the hardwood borer problem alone. I think that was management's first mistake. You can't do it all and you can't do it alone. We're all operating in a vacuum--the I&D researchers, the survey and control people, and the silviculturists. We're going to have to get together on multifunctional approaches to obtain workable solutions.

If I can make a recommendation, it is that we must stress the silvicultural control strategy, an integrated silvicultural control strategy, involving all disciplines and all functions. We must develop and demonstrate management alternatives--cost effective management alternatives. We must get a better feel for minimums--let's operate with minimums for a change. Identify the minimum biological and behavioral information we need which permits us to understand how to manipulate insect populations. We must accept 51 percent accountability or a 51 percent chance of success when it is necessary to get on with the job.

FI&DM also needs minimum biological information for survey and detection systems. I made a survey of the folks in our organization, asking them, "What do you need from research? How can research help you?" I got the answer, "Well, we want survey and detection systems." Apparently, FI&DM also fails to appreciate that we aren't going to survey or detect the first thing if the forest managers cannot relate to our findings or if they have no plans to use the information.

For too long the insect and disease tail has been wagging the forest management dog when pest problems were involved. We have been good salesmen over the years in encouraging awareness of the need for functional responses to insect and disease inconveniences. It is now time to put the I&D role in perspective. Emphasize development of tools to which users can relate, which users need. We are quickly becoming aware that we cannot continue to work in our respective functional vacuums. The only way I feel we are going to get the job done is to begin to appreciate the supportive role of insect and disease technology and exert ourselves a little more to interact with the people with the real problems--the forest managers, the silviculturists, and the economists.

Summary

Research Needs, Priorities, and Implementation of Research Results

As Seen by User Groups

Hardwood Product Uses and Trends

Domestic production and consumption of hardwood timber products have dropped about 13 percent in the last 25 years. The major factor in this decrease has been the declining use of round hardwood for fuel. Conversely, total domestic production and consumption of hardwood industrial roundwood products (i.e., pulpwood, saw logs, and veneer logs) have risen substantially. Projections of trends in population growth, economic activity, and disposable personal income suggest increasing demands for most hardwood products including high-quality logs for use in cabinets, furniture, and paneling.

Although trends in inventory, growth, and removals indicate that the hardwood timber situation has been improving for most species, we face some definite problems. Much of the larger size timber suitable for the manufacture of high-quality lumber and veneer occurs as single trees or groups of trees that may not be economically accessible or available for sale because either they are too widely dispersed or they grow on privately owned tracts held for purposes not compatible with timber harvesting.

With current management practices, the outlook beyond the next few years is not promising because projected demands will rapidly outstrip projected supplies. If hardwood forest lands are intensively managed, however, projected demand and supply will closely coincide for several decades. Effective protection against hardwood borers is vital to such a management effort.

Needed Research

Improved borer survey techniques are necessary to: (1) assess and predict borer population levels and damage, (2) determine the need to implement a borer control program, and (3) evaluate the results of a borer control program. The development of these techniques is of the highest priority.

Closely related to the development of survey techniques is the need to understand the total impacts of borer damage. Without this information, necessary research cannot be supported and the need for control actions cannot be determined. Much good information is already known but more is needed.

Site, stand, and individual tree characteristics that predispose trees to borer attack must be identified. Research should develop a series

of hardwood management alternatives based on sound but not unnecessarily detailed or protracted interdisciplinary research. The management alternatives must be as cost-effective as possible and must be compatible with existing and anticipated hardwood management systems. For example, in many cases harvesting is the only management tool now being used and proposed borer control strategies must recognize this fact.

Borer research should strive to provide management prescriptions for a variety of stands managed for different purposes. For example, prescriptions are needed for small woodlot owners whose primary objectives may be timber production coupled with recreation. Conversely, management devoted solely to supplying the hardwood lumber market has other requirements. Profits in hardwood industries are directly linked to yields of high-value material. Thus, successful borer control must prevent damage in all but the central core of stem wood. To achieve this protection, borer research should focus on developing management alternatives in young, even-aged managed stands because more and more of our hardwoods will be grown under these conditions. Except in specialized cases, direct control by chemical insecticides, behavioral chemicals, or biological agents will probably not prove practical.

To produce the required management prescriptions, borer research should be structured along multidisciplinary lines. This does not necessarily imply multidisciplinary research work units but it does imply a need to integrate borer research with pathology, economics, silviculture, mensuration, and utilization--then present a complete package to users through an aggressive implementation program.

Research Implementation

Research should not be too conservative with respect to recommending management alternatives. Many user groups would welcome tentative recommendations rather than wait for thoroughly researched solutions requiring considerably more time to develop. To facilitate communication and implementation of research results, Forest Service entomologists and industry need to establish closer ties. The list of hardwood trade executives and associations provided by J. L. Gundy (Appendix IV) should be helpful in suggesting a broad range of contacts.

Increased attention should also be given to working with service foresters, timber buyers, and our own State and Private Forestry (S&PF) personnel. Finally, with the help of S&PF, an increased effort is needed to popularize research results and implement appropriate technology.

RECOMMENDATIONS AND FUTURE PLANS

1. The Southern Station plans to increase their hardwood borer research effort by 1 SY and the Northeastern Station (1) will expand their effort to other insects that affect quality of high value hardwoods and (2) will develop a problem analysis on cherry defects and oak regeneration problems in F.Y. 1977.

2. Much basic life-history borer research at the Southern Station could be concluded and reoriented, in part, to developing a practical survey method of current and past borer populations. These populations should be correlated with host damage and their effects on tree quality over time--an effort that should be coordinated with NE-3102 at Delaware, Ohio. When initiated, this work should be closely linked to the work projected in Recommendation No. 4.

3. Borer research at the Northeastern Station is progressing well. If current research on identification and removal of brood trees proves, by 1977, to have practical application, this effort should be expanded at the NE Station and similar work should be initiated at the Southern Station and perhaps the Rocky Mountain Station to evaluate this practice for as many site and stand conditions as possible. (See Recommendation No. 4.) The Station should continue its research to (1) demonstrate the presence of one or more red oak borer pheromones and (2) use them to develop a practical system to manage red oak borer populations.

4. Northeastern Station borer researchers and Forest Pest Management personnel plan, in the summer of 1977, to initiate a cooperative effort to detect and evaluate current populations of the red oak borer. If successful, this capability could be used to estimate current and projected damage.

5. Borer research at the Rocky Mountain Station should appropriately pursue the goals of (a) obtaining registration of insecticides and sex pheromones for direct control of carpenterworms and ash borers; and (b) developing reliable borer survey techniques and relating these to expected damage levels. This research would have to be coordinated closely with work at the Southern Station--particularly if the latter increases their research on survey methods.

6. Continuing effort is appropriate to improve the existing coordination between borer control specialists and specialists in mensuration, silviculture, forest economics, utilization, insect and disease management, cooperative forestry, and industry to help insure the most practical and profitable borer research program possible.

7. Efforts should be increased to educate the public and user groups on the nature and extent of impacts caused by hardwood borers and to more effectively implement research results. At least the following six steps could be taken.

   a. Increase the use of trade journals as publication outlets and broaden user group contacts. The list of hardwood trade association executives provided by Jim Gundy (Appendix IV) should be helpful in this regard.

   b. Increase (Northeastern Station and Southern Station) the practice of periodic attendance at hardwood manufacturers' meetings to discuss research needs and results.

   c. Working closely with S&PF, develop a strategy to more effectively work with and relate to private landowners, consulting foresters, and timber buyers.

   d. The Northeastern Station should publish an illustrated leaflet aimed at increasing public and industry awareness of red oak borer problems.

   e. The Southern Station should take the lead in publishing an illustrated guide for recognizing and identifying the major hardwood borers and their damage in the South and Southeast.

   f. The North Central Station should produce an illustrated publication of walnut pests for public and industry use.

8. We appreciate the pledged support of the Southern Hardwood Lumber Manufacturers Association for a hardwood borer research program. Future research planning efforts should consider this support.

APPENDIX I.

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APPENDIX II.

RELATIONSHIP BETWEEN BORER ATTACK AND DISCOLORATION AND DECAY

by

Frederick H. Berry[1/]

Discoloration and decay are frequently associated with wood borer galleries in living trees. In some cases, the wood-boring insects have opened the way for infection into locations already suitable for fungus growth; in other instances the insects may improve conditions for decay.

In soft maple, "worm holes" are invariably surrounded by a fairly extensive greenish-brown stain that forms a more-or-less star-shaped pattern on the faces of cut logs. One or more species of ambrosia beetles may be responsible for the tunnels. The stain is probably caused by fungi carried into the tree and used as food by the beetles.

In several recent studies we have shown the importance of borer wounds as entry courts for decay fungi.

In a study of decay in upland oak stands in Kentucky, insects were second only to fire scars as entry courts for decay fungi (1). Almost 16 percent of 490 infections occurred through insect wounds, accounting for about 9 percent of the total decay volume.

A study of decay in the central hardwood region of Ohio, Indiana, Illinois, and Missouri revealed that about 10 percent of 1,824 infections occurred through insect wounds and about 5 percent of the total decay volume was associated with these wounds (3).

In northern red oak (*Quercus rubra* L.), we found that 15 of 128 infections (12 percent) took place through insect wounds and about 5 percent of the total decay volume was associated with these wounds (2).

In hickory, however, insect wounds were relatively unimportant as entry courts for decay fungi. Only 4 of 115 infections (3 percent) took place through insect wounds and the decay was less than 0.5 percent of the total decay volume (4).

Occasionally, we have found basidiocarps or fruiting bodies of heart rot fungi in the hollow galleries caused by long-horn beetles and other wood borers.

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APPENDIX III.

COMMENTS ON THE LOCUST BORER AND BLACK LOCUST

by

Edward H. Wollerman[1/]

Economics.--What values, actual or potential, justify research on locust borer control or application of control methods? Markets in the past included insulator pins used on cross-arms of electric utility poles. In 1925, 18,000 cords were used to make 25 million pins selling for 20-23 dollars per thousand. Smaller value markets were fence posts (20,000 cords in 1926) and poles under 30 feet (1,797 in 1923).

Potential.--Although black locust and the locust borer are native to North America, the tree has been introduced into Europe and forests of black locust have grown to occupy 830,000 acres from France to Russia. In Hungary, the utilization of black locust is wide-ranging both in industry and in agriculture.

The size and quality prescriptions of locust industrial wood are included in more than 40 standards. The economical utilization of locust timber, however, is limited by the small diameter of its wood material.

Problems.--Throughout the past century, black locust was the main species on the Plain in Hungary. Probably due to much off-site planting, however, the species has frequently exhibited poor form and growth. It is an aerobian species and, for this reason, it cannot be grown on deep-seated, inundated soils or on meadow soils with high-ground water level.

In the United States, we, too, have frequently disregarded site requirements. By planting thousands of acres of black locust for land reclamation, we have greatly increased the borer problem.

Solutions.--The best sites are stable slopes (not spoils banks) or sandy soils with moderate rainfall, good drainage, and mixed tree species composing the forest. These sites produce optimum tree growth while minimizing borer attack and the resulting lower value of wood products.

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